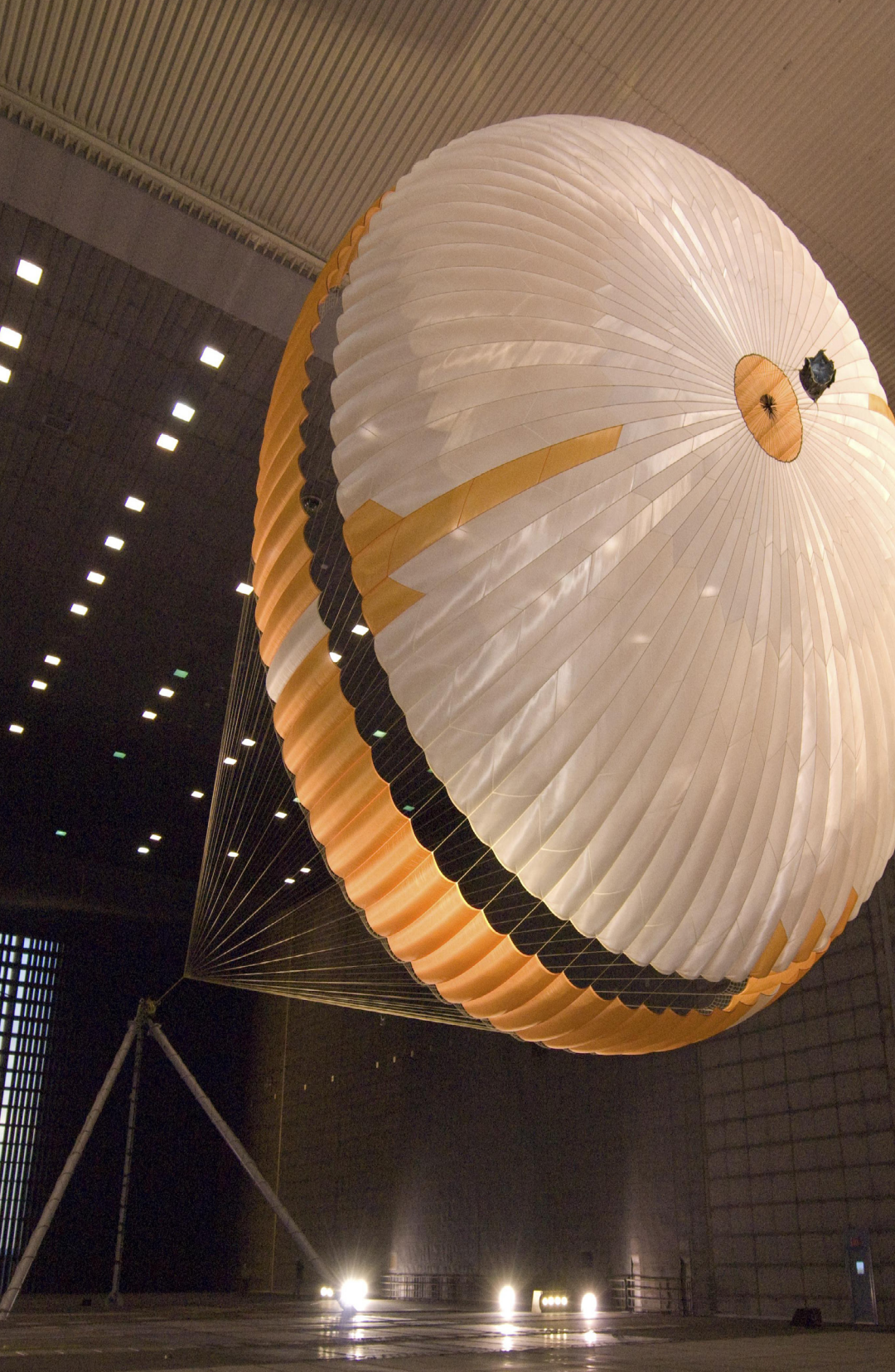


National Aeronautics and Space Administration



**Ames Research Center
SBIR/STTR
Technology Investments
January 2012**

www.nasa.gov



Foreword

This technology portfolio highlights new innovations developed via SBIR and STTR Phase II contracts that are managed by subject matter experts at Ames Research Center. Included is a brief description of the research and development efforts ending in December of 2010, or ongoing through 2013. These technologies have created partnership opportunities between small businesses and NASA. NASA's goal is to encourage program and project managers, prime contractors, and others to make use of these new technologies under development by the SBIR/STTR Program community to leverage their own efforts. All abstracts for these technologies can be found online at www.sbir.nasa.gov.

Please note, if program or project funding is available, no further competition is necessary to award an SBIR Phase III contract.

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SBIR/STTR

The Small Business Innovation Research (SBIR) Program provides opportunities for small, high technology companies to participate in Government sponsored research and development (R&D) efforts in key technology areas.

This program provides significant sources of seed funding for the development of innovations. *Current SBIR Phase I contracts last for 6 months with a maximum funding of \$125,000, and Phase II contracts last for 24 months with a maximum funding of \$750,000.

The STTR Program awards contracts to small business concerns (SBC's) for cooperative research and development with a nonprofit research institution (RI), such as a university. The STTR *Phase I contract is an opportunity to establish the feasibility and technical merit of a proposed innovation with projects receiving up to \$125,000 for a 1 year effort. STTR Phase II contracts continues the most promising Phase I projects based on scientific and technical merit, expected value to NASA, and commercial potential. STTR Phase II contracts are limited to \$750,000 for 2 years.

* Award amounts subject to change.

Expedited Procurement for Technology Development or Research Support

NASA may award Phase III contracts for products or services with non-SBIR/STTR funds. The competition for SBIR/STTR Phase I and Phase II awards (by any federal agency) satisfies competition requirements of the Armed Services Procurement Act, the Federal Property and Administrative Services Act, and the Competition in Contracting Act. Therefore, an agency that wishes to fund a Phase III project is not required to conduct another competition in order to satisfy those statutory provisions. Phase III work may be for products, production, services, R/R&D, or any combination thereof that is derived from, extends, or logically concludes efforts performed under prior SBIR funding agreements, from any government agency. A federal agency may enter into a Phase III agreement at any time with a Phase I or Phase II awardee. There is no limit on the number, duration, type, or dollar value of Phase III awards made to a business concern. There is no limit on the time that may elapse between a Phase I or Phase II and a Phase III award. The small business size limits for Phase I and Phase II awards do not apply to Phase III awards.

NASA wide SBIR search tool:

[https://ehb8.gsfc.nasa.gov/sbir/public/technologySearch/
searchAction.do?requestFrom=NASASBIRHome](https://ehb8.gsfc.nasa.gov/sbir/public/technologySearch/searchAction.do?requestFrom=NASASBIRHome)

Government wide SBIR search tool:

http://web.sba.gov/tech-net/public/dsp_search.cfm

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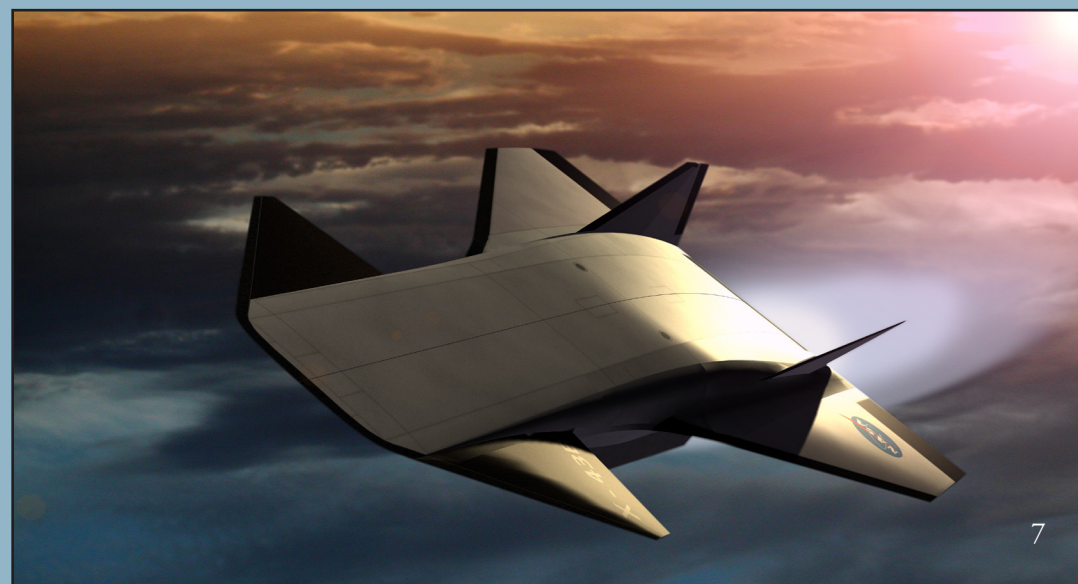
Areas of Research

The technologies described herein were solicited for in alignment with NASA Mission Directorates.

At the time of the solicitations, the mission directorates were:

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- **Exploration Systemspg. 36**
- **Sciencepg. 72**
- **Space Operationspg. 108**
- **STTR pg. 114**

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Microscopic Analysis and Modeling of Airport Surface Sequencing

Mosaic ATM, Inc.**Technical Abstract**

Although a number of airport surface models exist and have been successfully used for analysis of airport operations, only recently has it become possible to conduct detailed validation of such models through the use of airport surface surveillance data. In this effort, we propose to go a step further than existing models, by actually incorporating empirically-derived airport surface control practices into NASA's overall airport simulation modeling capability. This effort will produce tools to support fundamental research of the concept and requirements for airport operations in the Next Generation Air Transportation System (NextGen) by providing microscopic airport surface modeling components that provide higher fidelity and greater validity of modeling than previously available. Through this effort we will use the Surface Operations Data Analysis and Adaptation (SODAA) tool to conduct detailed analysis of airport surface operations using actual data.

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Rapid Estimation of Aircraft Performance Models using Differential Vortex Panel Method and Extended Kalman Filter

Optimal Synthesis**Technical Abstract**

The problem of estimating the aerodynamic models for flight control of damaged aircraft using an innovative differential vortex lattice method tightly coupled with an extended Kalman filter was investigated during the Phase I research. The approach exploited prior knowledge about the undamaged aircraft to reduce the order of the estimation problem. Probing maneuvers were designed to improve the observability of the system dynamics. The derived performance model was then be used to determine the aircraft flight envelope, performance parameters and the maneuver limits. The estimated data can be used as the basis for designing safe landing guidance laws for damaged aircraft. Phase II research will refine the algorithms developed during the Phase I research and create a standalone software implementation. Structural dynamic computations and control power estimation will be included in the software. Operation of the software will then be demonstrated at near real-time speeds. All the algorithms and software developed under the proposed research will be supplied to NASA at the end of Phase II. Human-in-the-loop simulations and flight test evaluation of the system will be undertaken during the Phase III work.

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Advanced Data Mining and Deployment for Integrated Vehicle Health Management and the Space Vehicle Lifecycle

Michigan Aerospace Corporation

Technical Abstract

In a successful Phase 1 project for NASA SBIR topic A1.05, "Data Mining for Integrated Vehicle Health Management," Michigan Aerospace Corporation (MAC) demonstrated its SPADE anomaly detection software to key personnel in NASA's Intelligent Systems Division (ISD) and with data from our partners at Boeing, SpaceX and GMV Space Systems. The feedback from these demonstrations was used to establish future development directions for Phase 2. Phase 2 will consist of three major efforts: 1) the design and implementation of the Taiga system, a next-generation enhancement of the SPADE software, 2) an investigation into combining complementary functionality of Taiga with existing code at ISD including the Inductive Modeling System, Mariana and others, and 3) the implementation of a prototype automatic parallelizer, in cooperation with subcontractor Optillel Solutions, for a subset of C++ useful for hardware acceleration of machine learning applications. The scope of the interaction with researchers in NASA ISD will be to explore the relationships between IMS and Taiga and gauge benefits such as Data Handling, Feature Reduction, Visualization and Explainability. We will also investigate heterogeneous ensemble methods by analyzing the Mariana system. Optillel's C++ Parallelizer will reduce MAC's development costs for parallelizing C++ code for multi-core chips and clusters. This effort will build on Optillel's existing body of work that supports graphical programming languages, and will extend their technology to the analysis and parallelization of C++ code. Both the Taiga system and Optillel's prototype have significant commercialization potential in industries as diverse as Chemical, Pharmaceutical, Manufacturing and Aerospace.

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Computational Model and Measurement Tool for Evaluating the Design of Flight Deck Technologies

Aptima, Inc.

Technical Abstract

The runway safety issue has been on the Most Wanted list of the National Transportation Safety Board since the list's inception in 1990. The FAA has responded by implementing two ground surveillance technologies at major U.S. airports to reduce the risk of runway incursions. However, both technologies route information through air traffic control (rather than directly to pilots), which significantly delays safe responses. Several flight deck technologies that communicate information directly to pilots are currently in development. However, there is a need for tools to rapidly test the flight deck technologies early in the design process and measure their impact on pilot performance prior to implementation. We propose to develop two tools that can be used together or independently to evaluate performance of flight deck technologies aimed at improving runway safety. We will deliver a computational cognitive model (Adaptive Control of Thought-Runway Safety; ACT-RS) that realistically emulates pilot performance, thus reducing the need for human pilots early in the design process. In addition, we will deliver a measurement tool (Performance Measurement (PM) Engine) that can measure the impact of the flight deck technology on the performance of ACT-RS and a human pilot, making it useful across the technology lifecycle.

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Elastomeric Dampers derived from First-Principles-Based Analytical Simulation

Materials Technologies Corporation

Technical Abstract

Lead-lag motions of rotor blades in helicopters require damping to stabilize them. In practice, this has necessitated the use of external hydraulic dampers which suffer from high maintenance costs. High operational (lifecycle) cost has prompted rotorcraft industry to use elastomeric lead-lag dampers that result in “dry” rotors. However, complex behavior of elastomers provides challenges for modeling such devices, as noted by rotorcraft airframers. Currently used analytical models oversimplify the complexity of operational environment and make radical assumptions about operating parameters that, at best, lead to excessively simplistic, and often unreal, device models. These first order linear device models require costly and time consuming experiments to construct them; moreover, they do not directly relate to either the material characteristics or the geometric configuration. In Phase-I SBIR, MTC team pursued a fundamentally radical approach wherein elastomeric dampers are derived from first-principle-based modeling rather than device model-based analyses. Our Phase-I program was tailored towards successfully demonstrating closed loop simulation, i.e. a finite element based modeling of elastomeric materials integrated into a multibody dynamics framework for rotorcraft analysis. During Phase-II, comprehensive and sophisticated material models will be implemented and streamlined into a single comprehensive analysis framework. These implementations will be fully validated against bench and flight test data of Bell M429 elastomeric dampers. These program objectives will be accomplished via collaborative tripartite partnership with Bell Helicopter and Georgia Tech.

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Computational Wind Tunnel: A Design Tool for Rotorcraft

Sukra Helitek, Inc.

Technical Abstract

During initial design studies, parametric variation of vehicle geometry is routine. In addition, rotorcraft engineers traditionally use the wind tunnel to evaluate and finalize designs. Estimation of rotor tunnel blockage is significantly more complex than bluff body corrections as the correction depends on operational characteristics such as rotor RPM and thrust produced. This proposal offers to develop an Integrated Design Environment (IDE) which can simulate a complete rotorcraft with or without wind tunnel walls including all the facility effects. At the heart of the innovation are: 1. An automated hybrid grid generator (viscous grids near the bodies and unstructured Cartesian grid everywhere else). 2. A robust and economical incompressible flow solver for the entire system of grids. 3. Momentum source based rotor model that is suitable and economical for simulating configurations with multiple rotors. In Phase I, the proof-of-concept developed used unstructured Cartesian grid for the model and wind tunnel. In phase II, the tool will be extended to hybrid grid with viscous grid near solid surfaces and will include several tools including a simple CAD like geometry manipulation tool and pre- and post-processing tools all integrated in one environment to facilitate ease of use.

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On-Demand Special Use Airspace

Metron Aviation, Inc.**Technical Abstract**

We design and develop a Decision Support Tool (DST) that supports On-Demand Special Use Airspace (SUA) scheduling and flight plan optimization around SUA between Airline Operations Control (AOC), Military, Air Traffic Control System Command Center (ATCSCC), and Air Route Traffic Control Center (ARTCC) personnel. The tool allows AOC and ARTCC Traffic Management Unit (TMU) personnel to coordinate strategic and tactical plans, with a strategic look ahead time from days to less than 2 hours, and tactical plans up to the minute centered locally around an ARTCC airspace. The tool coordinates aircraft movement though vs around SUA. The tool allows for asynchronous communication of priorities associated with flight plans and flight plan amendments (contingency plans) between the AOC and ARTCC TMU specialist, allowing the ATCSCC and Military to view these priorities and TMU responses to them at any time. This technology will be developed to Technology Readiness Level (TRL) 2 at the end of Phase I, and TRL 4 prototype system by the end of Phase II.

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Trajectory Design to Benefit Trajectory-Based Surface Operations

Optimal Synthesis, Inc.**Technical Abstract**

Trajectory-based operations constitute a key mechanism considered by the Joint Planning and Development Office (JPDO) for managing traffic in high-density or high-complexity airspace in the Next-Generation Air Transportation System (NextGen). With this concept applied to surface operations at major airports, NASA's NextGen-Airportal Project is exploring the use of surface 4-dimensional (4D) trajectories, which use required times of arrival (RTAs) at selected locations along the route. Observing these RTAs as constraints along the taxi route, the flight still has many degrees of freedom in adjusting its state profiles (i.e., position, velocity, etc. as functions of time) to achieve the timing constraints. This research will investigate whether and how these degrees of freedom in trajectory control may be used to achieve desirable behaviors for the taxi operations. Previous research has applied the trajectory control freedom to assure passenger comfort by keeping the accelerations and decelerations within pre-specified limits, and yet there is still untapped flexibility in designing the trajectories. The proposed research will explore this trajectory design problem to achieve additional desirable behaviors, beginning with the consideration of fuel burn, emissions, and noise. A flight-deck automation experimental prototype will provide the platform for simulating the designs, augmented by models developed to evaluate environmental benefits. The findings will benefit future designs of flight-deck automation systems, as well as tower automation systems which rely on accurate understanding of the flight deck's operational behaviors to plan efficient and safe operations for the entire surface traffic.

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A Robust Flare Planning Logic for Unmanned
Aerial Vehicle Applications

Aurora Flight Sciences Corporation

Technical Abstract

Aurora Flight Sciences proposes to develop a flare planning methodology that would provide aircraft guidance during this critical phase of flight. The algorithms that Aurora seeks to leverage the reachability problem in the fields of Optimal Control and Hybrid Systems, using Rapidly-Exploring Random Trees (RRTs) and Falsification theory. To this end, Aurora proposes the innovation of applying a suitable version of these algorithms to the design of a flare maneuver guidance and planning logic. The planner will be capable of dynamically producing a flare maneuver that does not violate the aircraft flight envelope and other stipulated constraints. The planner will meet the robustness requirements stipulated in the topic solicitation; namely, it will apply to both impeded and unimpeded aircraft, and it will operate under significant weather disturbances. The main technical challenge in developing the planning logic is extending and applying the chosen control algorithms to 6-DOF aircraft dynamics models under the required variety of operating conditions. The ultimate goal of the Phase 2 effort is to demonstrate Aurora's algorithms in an appropriately sophisticated Hardware-in-the-loop simulation of an impaired aircraft during a flare maneuver.

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Prognostic and Fault Tolerant Reconfiguration Strategies for
Aerospace Power Electronic Controllers and Electric Machines

Impact Technologies, LLC

Technical Abstract

Impact Technologies has proposed development of a real-time prognostic and fault accommodation system for power converters and electro-mechanical (EM) drive applications. The main goal for this program is development of techniques that enable fault tolerant control based on diagnostic features from the coil winding and power transistors. During Phase I, Impact achieved substantial and promising results in three main technical areas that provide opportunities to maturing tools that enable PHM and reconfiguration techniques. The technical areas include: Transistor Performance, Motor/Actuator Performance, and Fault Tolerant Reconfiguration. During Phase II, a significant effort will be employed to further develop the automated ringing feature extraction feature, leakage current sensing capabilities, and reconfiguration techniques for continued motor operation. These efforts will lead to development of prototype sensors for IGBT aging detection and current leakage detection as a health indicator of aging effects in power drives. Moreover, Impact will demonstrate reconfigurable control techniques for fault accommodations in EM applications. The long term implications of a successful completion of this program will provide reliability and health management tools for mission and safety critical applications for NASA, commercial, and military enterprises.

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ACES-Based Testbed and Bayesian Game-Theoretic Framework for Dynamic Airspace Configuration

Intelligent Automation, Inc.

Technical Abstract

This SBIR effort is focused on developing a Dynamic Airspace Configuration (DAC) concept where-in ARTCCs can benefit from re-configuring airspaces based on Traffic Flow Management (TFM) restrictions, and the development of a preliminary Airspace Concept Evaluation System (ACES)-framework and initial algorithms to demonstrate that ARTCCs need to engage in a coordination framework of exchanging TFM restriction until they determine mutually-agreeable optimal airspace configuration. The development of algorithms that leverage and recognize the interactions and interdependencies between DAC and TFM is the key innovation of this effort. Some examples of expected operational improvements include 1) reduction in congestion and delays when sector capacities (Monitoring Alert Parameter or Dynamic Density) are violated, 2) reduction in controller workload and improved safety, 3) ability to accommodate user preferred routes and weather uncertainty and 4) achieve a balance between airborne delay and grounding holding delay. The SBIR Phase-I effort demonstrated how a combined DAC-TFM algorithm determines an optimal airspace configuration different from a DAC-only algorithm and could result in minimization of peak count and dwell time variance. The effort also included the design and preliminary implementation of a TFM model that uses ARTCC sector configuration to determine the delays that is generated, absorbed and propagated. The Phase II effort includes development of DAC-TFM framework as an enhancement to NASA's ACES- DADS (Dynamic Airspace Design Service) work and interaction of NASA's airspace partitioning DAC algorithms such as MxDAC, DAU slicing and Sector Combination algorithms with the TFM models using the same framework.

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Use-Driven Testbed for Evaluating Systems and Technologies (U-TEST)

Aptima, Inc.

Technical Abstract

NextGen will require the development of novel solutions to shape the airspace of tomorrow. Along with the ability to generate new systems and technologies comes the need to rigorously evaluate, and eventually validate, the effectiveness of these concepts. However, it is often challenging to translate simulation data into useful, integrated, and contextually-based assessments. Many critical findings are not identified for this reason, which could otherwise guide researchers toward advancements with NextGen technologies. Aptima proposes to develop the Use-driven Testbed for Evaluating Systems and Technologies (U-TEST), a flexible toolset that helps NextGen researchers to efficiently extract findings on pilot performance in simulated flight environments. Three primary components are: (1) context-capturing software will guide researchers to key events and allow important contextual information to be gathered for analysis; (2) a data integration platform that will automate organization of data sources into a format conducive to analysis; and (3) context-based analysis software that will enable deep, focused analysis by combining a quick-look function, an algorithm for focusing analysis, and context-based playback of key events and trials. U-TEST will be an extensible toolset that can help NextGen researchers improve the amount and quality of findings across a range of studies.

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Integrated Design and Analysis Environment for Safety Critical
Human-Automation Systems

Barron Associates, Inc.

Technical Abstract

Numerous advances have been made in recent years in the areas of flight deck design, aircraft modeling, resilient control, and vehicle health management. The combination of these complementary technologies promises to revolutionize aircraft systems and operations safety in the decades ahead. However, the task of safely integrating these technologies is becoming increasingly difficult as their level of complexity, degree of automation, and demands from their operational environment grow. The Next Generation Air Transport System (NextGen), while providing significant benefits in terms of increased capacity and safety, will exacerbate this situation due to the large numbers of new and existing systems that will be required to interoperate. The multidisciplinary nature of these systems is a significant factor that makes analyzing their safety characteristics extremely difficult. While many development tools exist to conduct deep analyses within individual disciplines, there is a lack of tools available for deep analysis of complex multidisciplinary designs. The proposed research seeks to create a new class of development tool that will allow designers of complex systems-of-systems to explore the dynamic interactions between system components to uncover systemic vulnerabilities, precursory conditions, and likely outcomes. The Phase I project generated an initial implementation of the software package Idea, an Integrated Design and Analysis Environment that could be used to model complex interdependencies between flight deck operations, flight deck controls and display, and the underlying physical components of the aircraft. The proposed Phase II effort will mature this software and expand its capabilities, resulting in a flexible, standards-compliant tool that is ready for beta testing and subsequent commercialization. It will focus on enhancements that support cross-disciplinary modeling and analysis of safety-critical human-automation systems.

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Physical Modeling for Anomaly Diagnostics and Prognostics

Ridgetop Group, Inc.

Technical Abstract

Ridgetop developed an innovative, model-driven anomaly diagnostic and fault characterization system for electromechanical actuator (EMA) systems to mitigate catastrophic failures. Ridgetop developed a MIL-STD-1553 bus monitor and a MIL-STD-1553 bus controller that simulates the aircraft data bus, reads the environmental (i.e., altitude) and operational (i.e., response of system) data of a system and determines if a fault is manifesting; and if true determines the root cause and symptoms of the fault. Once an anomaly is detected, the Model-based Avionic Prognostic Reasoner (MAPR) solves a user-outlined state-space model, symbolically, using a Gauss-Newton optimization method and the information from the MIL-STD-1553 bus. This algorithm outputs a list of best fitting parameters to match the command to the actual performance. Rules are programmed in, based on results from principal component analysis. The rules determine both fault mode and the severity of that fault. The rules can distinguish between two failure modes: Mechanical jam and MOSFET failure, and healthy. The real-time processing will allow for critical evolutions in flight safety and provides a game-changing approach to condition-based maintenance. Once deployed, flight safety can be improved by allowing the on-board flight computers to read from the MAPR and update their control envelope based on its evaluations, reducing damage propagation and increasing operational safety. In Phase 2, we will develop a functioning ground-based prototype of the technology to show the efficacy of the method. A ground-based version of the tool is the best candidate for development to ease adoption by testing in a low-risk environment; this tool will be demonstrated at the end of Phase 2. The MAPR concept is also applicable to any system with a state-space representation but at this point it has been developed with EMAs in mind. The MAPR prototype is at TRL 5 and will reach a TRL 7 by the end of Phase 2.

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Interfacial Design of Composite Ablative Materials

Advanced Cooling Technologies, Inc.**Technical Abstract**

This Small Business Innovation Research (SBIR) project proposes the development of a computational software package to provide NASA with advanced materials development capabilities for existing and new ablative materials used in the next generation thermal protection systems (TPS) of space vehicles. This materials development software package (MDSAM) can be used to optimize properties (high strength and low thermal conductivity) for both the virgin material as well as the char that forms during the operating conditions. It will provide atomistic-level information on char evolution and the degradation of thermo-mechanical properties. The proposed MDSAM will consist of the following two modules: (i) an experimentally validated, atomistic-level simulation engine capable of predicting the role of interfacial structure on the resin-to-carbon process and (ii) atomistically-informed continuum-level thermo-mechanical performance analyzer for composite ablative materials subjected to transient pyrolytic conditions. The underlying methodology and the software package will be transitioned to NASA scientists working on ablative materials development. In addition to developing a computational software package, we will address open, unsolved problems in the literature to support NASA's ablative materials development requirements. In the course of developing this methodology, we will produce significant scientific results on pyrolysis and materials properties that will be important to NASA.

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Fiber-Coupled Spectrometer for TPS Materials

ElectroDynamic Applications, Inc.**Technical Abstract**

EDA, Inc., in partnership with Penn State, has shown previously that the concept of embedding fiber optics within ablative TPS material has merit and should yield a successful implementation of a spectrometer "window" during a Phase-II development program. Optical instrumentation, such as optical spectrometers would provide benchmark data for fundamental flow, radiation, and materials modeling as well as provide operational correlations between vehicle reentry drag and radiation if implemented in a TPS flight test program. Without flight spectral data, and the appropriate modeling efforts, the power of prediction to assist in new heat shield design does not exist for reentry into other planetary atmospheres. This is a severe limitation for future space exploration missions which FiberPlug helps address.

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Flight Adaptive Blade for Optimum Rotor Response (FABFORR)
Continuum Dynamics, Inc.

Technical Abstract

While past research has demonstrated the utility and benefits to be gained with the application of advanced rotor system control concepts, none have been implemented to date on a production military or commercial rotorcraft. A key contributor to this fact is the inherent cost associated with installation and maintenance of these control systems, since many system designs require the replacement of a helicopter's rotor blades, rotor hub components, or both. The proposed work addresses this deficiency through the development of an on-blade full-span camber control system that reaps many of the known benefits of advanced rotor control in a retrofit design approach that has the potential to achieve production status due to its lower risks and costs compared to previous system concepts. The design leverages past work in the use of smart-material actuated bistable tabs for rotor blade tracking, with a newer integral actuation concept that will lead toward a more robust and flightworthy design.

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Stochastic Queuing Model Analysis to Support Airspace Super Density Operations (ASDO)

Optimal Synthesis, Inc.

Technical Abstract

NASA has been involved in extensive research efforts to develop advanced concepts and technologies, for the Next Generation Air Transportation System (NextGen) under different Research Focus Areas (RFAs). The Airspace Super Density Operations (ASDO) RFA seeks to develop efficient terminal area operations. It is expected that multiple ASDO concepts will be interacting with one another in a complex non-deterministic manner. Therefore, the overall terminal system performance may not be a straightforward combination of individual performance indices. It is also crucial that the overall system performance be robust to wind and operational uncertainties. The proposed research effort seeks to develop a fast-time, stochastic analysis tool based on queuing theory that can be used to evaluate the interaction and combined performance of multiple ASDO concepts. The utility of the approach was demonstrated under Phase I research. Phase II research seeks to achieve the following: (i) make enhancements to the modeling and simulation aspects of the approach, (ii) accelerate the stochastic simulation execution time using high-performance computing solutions, (iii) create software plug-ins for existing NASA research tools, (iv) conduct studies of NextGen terminal area concepts using the queuing simulation, and (v) develop a conflict free scheduling algorithm based on the queuing simulation.

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Market Mechanisms for Airspace Flow Program Slots

Metron Aviation, Inc.**Technical Abstract**

Metron Aviation, Inc. proposes to design a system to support a marketplace in which flight operators can exchange arrival slots in traffic flow management (TFM) initiatives such as airspace flow programs (AFPs) and ground delay programs (GDPs) while requiring no changes in FAA automation or procedures. The advent of AFPs in 2006 has generated many more potentially exchangeable resources that would be valued sufficiently differently by their owners to make a trade desirable. We believe that NAS users and the FAA would embrace such a marketplace and that it would enable users to collectively reduce their operating costs resulting from NAS congestion. Both FAA and NASA research has highlighted the need for efficient and equitable allocation of NAS resources and increased operational flexibility. Market-based mechanisms have been suggested for transferring system-imposed delay from more critical to less critical flights. No such capability is available to NAS users today. In this SBIR, we will show how the advent of AFPs changes the forces at work in a slot-trading marketplace, making its functions much more valuable to flight operators.

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Unmanned Aerial Vehicle Integration into the NAS

Metron Aviation, Inc.**Technical Abstract**

Technological innovations have enabled a wide range of aerial vehicles that can be remotely operated. Viable applications include military missions, law enforcement, border patrol, weather data collection, telecommunications, land use imaging, and cargo transport. NASA and other organizations have invested heavily in this unmanned aerial vehicle (UAV) research. UAVs can be flown in the National Airspace System (NAS) today, but only with special permission from the FAA a process that often takes 60 to 90 days. Moreover, permission is often contingent on heavy restrictions, such as accompanying the UAV with a manned chase plane, thereby nullifying the cost savings of a UAV. Full fruition of UAV technology will require incorporation of UAVs into mainstream air traffic management (ATM) practices, including traffic flow management flow control programs and possible creation of special use airspace (SUA). In this SBIR, we propose a UAV-to-traffic flow management (AIM-UAS) interface. This allows traffic managers to anticipate and track UAVs. In turn, this allows UAV operators to understand their impact on commercial air traffic and their involvement in traffic management activities.

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ATC Operations Analysis via Automatic Recognition of Clearances

Mosaic ATM, Inc.**Technical Abstract**

Recent advances in airport surface surveillance have motivated the creation of new tools for analysis of Air Traffic Control (ATC) operations, such as the Surface Operations Data Analysis and Adaptation (SODAA) tool, which is being used by NASA to conduct airport ATC operations analysis. What is missing from ATC operations analysis, however, is accessible and reliable data regarding the clearances issued by the controller and other communication conducted with the pilot that influences the behavior seen in the surveillance data. The reliance on voice communication in ATC operations presents challenges to the researcher who is trying to obtain data and conduct detailed analyses of ATC operations. During the Phase I effort, we designed and developed a prototype system to perform automatic speech recognition (ASR) of ATC clearances. We demonstrated the feasibility of recognizing ATC clearances from speech audio data and associating the clearance data with the flight that is the subject of the clearance. In the Phase II effort, we will create a complete prototype of the ATC speech recognition, processing and analysis capability in SODAA. In addition, we will integrate ATC speech recognition capabilities into a real-time application in the Surface Management System (SMS).

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Estimation and Prediction of Unmanned Aerial Vehicle Trajectories

Numerica Corporation**Technical Abstract**

There is serious concern about the introduction of Unmanned Aerial Vehicles (UAV) in the National Air Space (NAS) because of their potential to increase the risk of collision between aircraft. At present, many UAV platforms lack a Sense and Avoid (SAA) capability to mitigate collision risk, and this has prevented both the government and private contractors from using these platforms in critically needed reconnaissance, surveillance, and security enforcement missions. To demonstrate a SAA capability that is applicable to a wide range of UAV platforms, advanced trajectory estimation and prediction algorithms are developed and used to exploit a small collision avoidance radar currently under development for UAV operation. Collision prediction algorithms will assess potential risk in probabilistic terms using adaptive techniques that permit accurate predictions across long time horizons. Techniques to ensure these predictions are robust to modeling uncertainty increase the utility the developed SAA capability for realistic scenarios.

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Accelerating ATM Optimization Algorithms Using High Performance Computing Hardware

Optimal Synthesis, Inc.

Technical Abstract

NASA is developing algorithms and methodologies for efficient air-traffic management. Several researchers have adopted an optimization framework for solving problems such as flight scheduling, route assignment, flight rerouting, nationwide traffic flow management (TFM) and dynamic airspace configuration. Computational complexity of these problems have led investigators to conclude that in many instances, real time solutions are computationally infeasible, forcing the use of relaxed versions of the problem to manage computational complexity. The primary objective of the proposed research is to accelerate optimization algorithms that play central roles in NASA's ATM research, by parallel implementation on emerging high performance computing (HPC) hardware. The Phase I R&D effort implemented a Simplex-based Dantzig-Wolfe (DW) decomposition solver that exploits both coarse-grain and fine-grain parallelism in the sub-problem and master iterations of the DW decomposition. The implementation also exploits the sparsity in the problems, to manage both memory requirements and run-times for large-scale optimization problems. This parallel implementation was used to solve a Traffic Flow Management (TFM) problem with 17,000 aircraft (linear program with 7 million constraints), in 15 seconds. The implementation is 30% faster than the exact same code running on the CPU. It is also 16% faster than the NASA's current solution that implements parallel DW decomposition using the GNU Linear Programming Kit (GLPK) on an 8-core computer with hyper-threading. Based on the promising Phase I results, the Phase II R&D effort will explore Mixed Integer Linear Programming (MILP) methods to solve optimization problems arising in the terminal area and on the airport surface, in addition to DW decomposition for the nationwide TFM problem. Phase II work will develop operational prototypes of the algorithm implementations on HPC hardware, and deliver them to NASA for further evaluation.

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TBA-Contract Under Negotiation

Probabilistic Remaining Useful Life Prediction of Composite Aircraft Components

Global Engineering and Materials, Inc

Technical Abstract

A Probabilistic Fatigue Damage Assessment Network (PFDAN) toolkit for Abaqus will be developed for probabilistic life management of a laminated composite structure with both microcracking induced stiffness degradation and cyclic loading induced delamination crack growth without remeshing. It is based on a high fidelity Fatigue Damage Assessment Network (FDAN) which includes 1) a coupled continuum damage and discrete crack model for ply damage characterization; 2) a moment schema finite element coupled with XFEM for efficient crack growth simulation in a thin ply; 3) a mixed mode fatigue delamination module to account for the mode mixity and failure mode interaction; and 4) an adaptive fracture process zone model for mesh independent delamination growth. A reduced-order model of FDAN will be generated using a combined response surface and a Gaussian process surrogate model builder to perform the subsequent probabilistic analysis efficiently. For the module verification and validation, experimental studies at the sub-component level will be performed along with the use of a damage monitoring and characterization system. The developed toolkit will be used to perform damage prognosis and risk informed life management using SHM data. GEM has secured commitments for technical support and commercialization assistance from Clarkson University, Sikorsky Aircraft, and Boeing.

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Distributed Data Mining for Aircraft Health Management

Mitek Analytics LLC**Technical Abstract**

Aircraft Flight Operations Quality Assurance (FOQA) programs are implemented by most of the aircraft operators. Vast amounts of FOQA data are distributed between many computers, organizations, and geographic locations. This project develops methodology for transforming such distributed data into actionable knowledge in application to aircraft health management from the vehicle level to the fleet level to the national level. The distributed data processing methodology provably obtains the same results as would be obtained if the data could be centralized. The data mining methods are efficient and scalable so that they can return results quickly for 10Tb of distributed data. This data mining technology that we call Distributed Fleet Monitoring (DFM) developed in SBIR Phase I satisfies these requirements. The data are transformed into models, trends, and anomalies. The model training and anomaly monitoring are formulated as convex optimization and decision problems. The optimization agents are distributed over networked computers and are integrated through remote connection interface in a scalable open grid computing framework. Though the data and the computations are distributed, they yield provably the same optimal solution that would be obtained by a centralized optimization. DFM feasibility was demonstrated in the problem of monitoring aircraft flight performance from fleet data using large realistic simulated datasets. We demonstrated efficient computation of quadratic optimal solution by interacting distributed agents. The feasibility demonstration successfully recovered aircraft performance anomalies that are well below the level of the natural variation in the data and are not directly visible. The algorithms are very efficient and scalable. Phase I demonstration extrapolates to processing 10Tb of raw FOQA data in under an hour to detect anomalous units, abnormal flights, and compute predictive trends.

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A High Order Accuracy Computational Tool for Unsteady Turbulent Flows and Acoustics

Frendi Research Corporation**Technical Abstract**

Accurate simulations of unsteady turbulent flows for aerodynamics applications, such as accurate computation of heat loads on space vehicles as well the interactions between fluids and structures is of utmost importance to the aerospace industry and NASA. Using a Finite Element Framework suited for both fluids and structures, we propose to continue building on the successes of Phase I by adding various turbulence solution methodologies as well additional multi-disciplinary physics to address complex problems with complex geometries, while maintaining high order accuracy of the framework.

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RotCFD: A Viscous Design Tool for Advanced Configurations

[Sukra Helitek, Inc.](#)

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Technical Abstract

During initial design studies, parametric variation of vehicle geometry is routine. In addition, rotorcraft engineers traditionally use the wind tunnel to evaluate and finalize designs. Correlation between wind tunnel results and flight tests, when not good, have been often attributed in part to uncertainty in blockage corrections. Estimation of rotor blockage is significantly more complex than bluff body corrections as the correction depends on operational characteristics such as rotor RPM and thrust produced. This proposal offers to develop an Integrated Design Environment (IDE) which can simulate a complete rotorcraft with or without wind tunnel walls including all the facility effects. At the heart of the innovation are: 1. An automated hybrid grid generator. (viscous grids near the bodies and unstructured Cartesian grid everywhere else) 2. A robust and economical incompressible flow solver for the entire system of grids. 3. Momentum source based rotor model that is suitable and economical for simulating configurations with multiple rotors. In Phase I, the proof-of-concept developed used unstructured Cartesian grid for the model and wind tunnel. In phase II, the tool will be extended to hybrid grid with viscous grid near solid surfaces and will include several tools including a simple CAD like geometry manipulation tool and pre- and post-processing tools all integrated in one environment to facilitate ease of use.

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Spectroscopic Dosimeter

Merril Corporation of Utah, dba MSI Photogenics

Technical Abstract

Analysis of Phase I test data demonstrates that the Photogenics Spectroscopic Dosimeter will detect neutron energies from 0.8 up to 600 MeV. The detector efficiencies in the energy region of interest to NASA of 0.5 to 150 MeV were predicted by MCNP-X models. These models were partially confirmed by the tests at the EAL and LANSCE, with a high confidence in the data for the 1-14 MeV range and a confirmation of the detector's spectroscopic capabilities between 15-150 MeV. Further analysis of the high energy data will be performed in Phase II. Using the detection efficiencies determined Phase I and the IRCP74 damage coefficients, doses have been calculated for the neutron fluxes encountered in the test facilities. During Phase II a full-scale working model of the spectroscopic dosimeter will be fabricated and tested.

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Enhancing NASA's Procedure Representation Language to Support Planning Operations

TRAC Labs, Inc.

Technical Abstract

Automation and autonomy are key elements in realizing the vision for space exploration. The NASA Exploration Technology Development Program (ETDP) has been developing several core autonomy capabilities, one of which is called a procedure representation language (PRL). PRL can be automatically translated into code that can be executed by NASA-developed autonomous executives. Another type of automation being developed by ETDP is automated planning aids. These will be needed to increase the number of missions that existing levels of flight personnel must be able to handle. But PRL has few constructs to enable automated planners and schedulers to take advantage of the procedures resulting from PRL. In Phase 1 we developed extensions to PRL to add planning information resource, constraints and sub-procedural information so as to produce code useable by automated planning software. In this project, we propose to develop an interactive planning aid for flight controllers to show that such an aid can process our enhanced PRL files to generate mission plans and to test their feasibility via an execution system. Besides refining our previous modeling efforts, this work will show that the availability of computer-useable planning information can lead to practical applications of NASA's automated planning efforts.

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Procedure Integrated Development Environment (PRIDE)

S&K Aerospace**Technical Abstract**

NASA captures and distributes operational knowledge in the form of procedures. These procedures are created and accessed by a range of people performing many different jobs. These people have different needs for procedure data and different ways of interacting with procedures. We propose an Procedure Integrated Development Environment which will present different editing modes and different views depending on the users and tasks, but will use a consistent data representation for all users. We propose to connect the editing environment to other tools and systems that are useful to procedure development, including recon databases and verification tools. We propose to build this environment on the basis of an existing prototype, PRIDE, which was developed for the Engineering Directorate of Johnson Space Center.

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Efficient Techniques for Formal Verification of PowerPC 750 Executables

Aries Design Automation, LLC**Technical Abstract**

We will develop an efficient tool for formal verification of PowerPC 750 executables. The PowerPC 750 architecture is used in the radiation-hardened RAD750 flight-control computers that are utilized in many space missions. The resulting tool will be capable of formally checking: 1) the equivalence of two instruction sequences; and 2) properties of a given instruction sequence. The tool will automatically introduce symbolic state for state variables that are not initialized and for external inputs. We bring a tremendous expertise in formal verification of complex microprocessors, formal definition of instruction semantics, and efficient translation of formulas from formal verification to Boolean Satisfiability (SAT). We will also produce formally verified definitions of the PowerPC 750 instructions used in the project, expressed in synthesizable Verilog; these definitions could be utilized for formal verification and testing of PowerPC 750 compatible processors, for FPGA-based emulation of PowerPC 750 executables, as well as in other formal verification tools to be implemented in the future.

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Automated Test Case Generation from Highly Reliable System Requirements Models

Safeware Engineering Corporation

Technical Abstract

Software testing is a complex and expensive phase of the software development cycle. Effective software testing is especially important in mission-critical software, where erroneous behavior poses a risk to safety or mission success. Automated test case generation can make testing more efficient and effective, saving resources and reducing risk. Under Phase 1, Safeware Engineering Corporation successfully developed the algorithms necessary to streamline software testing by automatically generating test cases directly from SpecTRM-RL models. SpecTRM-RL (Specification Tools and Requirements Methodology Requirements Language) is a requirements language that was designed to be highly readable, allowing even non-specialists to understand them, but is also completely formal. Test cases generated from the black-box models written in SpecTRM-RL will focus on the intended behavior of the system. The test case generation tool will be designed to allow the user to choose between a smaller set of test cases, allowing for more rapid error identification, and a larger set providing more comprehensive coverage. The phase II effort will implement these algorithms, adding test-case generation to SpecTRM, the tool suite which allows for editing, analysis and execution of SpecTRM-RL models. The new test case generation tools will be tested on the Max Launch Abort System.

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Quantifiable and Reliable Structural Health Management Systems

Acellent Technologies, Inc.

Technical Abstract

Under Project Constellation, NASA is developing a new generation of spacecraft for human spaceflight. A significant percentage of the structures used in these spacecraft will be made of composite materials, and the Ares V payload shroud will be one of the largest composite structures ever built. This offers many challenges, not only for design and manufacturing, but also for inspection and maintenance. Inspection of large composite structures using traditional NDE methods is time consuming, expensive, and often not possible when access is limited (e.g. covered by a thermal protection system), resulting in a conservative (higher weight) design. Acellent proposes to develop a robust, state-of-the-art structural health monitoring (SHM) system to overcome these concerns. The Phase II will optimize the design and quantify the benefits for SHM on the Ares V payload shroud, and then expand the results to include other Ares V components such as the Altair Lunar Lander Structure, Earth Departure Stage (EDS) payload adapter, forward skirt and intertank, and the Core-to-EDS interstage. The proposed solution will be capable of detecting and quantifying damage with a high probability of detection (POD), accurately predicting the residual strength and remaining life of the structures with confidence, and providing information that will allow appropriate preventative actions on the monitored structure.

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HyDE Enhancements for ISHM Deployment

Impact Technologies, LLC**Technical Abstract**

Impact Technologies LLC, with the support of Palo Alto Research Center (PARC), proposes to continue developing key enhancements to NASA's Hybrid Diagnostic Engine (HyDE) that represent valuable and, in some cases, critical features for Integrated System Health Management (ISHM) developers in NASA and non-NASA application domains. Specifically, the proposed program will be focused on attaining three milestones. The first goal is to achieve commercial-grade readiness of a HyDE Developers Pack (HyDE DP) to TRL 6 or higher. To facilitate Phase III NASA transition, the second program goal is deploying HyDE DP to Kennedy Space Center's (KSC) Integrated Ground System in support of the Constellation Program. Finally, to facilitate Phase III commercial transition and dramatically improved the embedded capability of HyDE, preparation for Beta-site deployment and tech transition with PARC on a commercial printing platform will be performed. Building off the significant Phase I SBIR accomplishments, the Impact team believes that the proposed Phase II program is the ideal mix of innovative development work in the form of modeling, simulation, validation and verification tools for HyDE DP and tech transition activities designed to position HyDE as the diagnostic and reasoning engine for a broad application space that spans NASA, commercial and military domains.

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Water Reclamation using Spray Drying

NanoMaterials Company**Technical Abstract**

This purpose of this project is to develop a spray drying prototype to for the recovery and recycle of water from concentrated waste water recovery system brine. Spray drying is a one step, continuous process where a solution, slurry, sludge or paste is transformed into a dry solid and clean water. The dry solids powder is easy to transfer and does not foul surfaces. The process is suitable for dewatering brine from the vapor compression distillation processor and other sources. It may serve as a backup processor for one or more existing water recovery systems unit processors. We will employ alternative heating methods and advanced process control.

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A Super Cooled, Non-toxic, Non-flammable Phase Change Material Thermal Pack for Portable Life Support Systems

Paragon Space Development Corporation

Technical Abstract

The continuation of concept development and test of a water-based, advanced Phase Change Material (PCM) heat sink is proposed. Utilizing a novel material choice for both an expansion diaphragm and the PCM case itself, the PCM can accommodate both the expansion of the freezing water-based material and very low temperature of approximately -250F. The water-based PCM itself would be non-toxic and non-flammable, but additives will be included to preclude deterioration of either the PCM container or the diaphragm material. The use of a water-based PCM gives the highest heat capacity for the mass. This is highly limited due to the needs for portability as required for an Extra-Vehicular Activity (EVA). The total heat capacity of an operational unit would be for 4 hour duration EVA use. Through a logical progression of tasks including concept of operation formulation, requirements formulation, concept design reviews and detail design reviews that include design and thermal analysis using Thermal DesktopTM models, this effort can progress from the TRL 3 achieved in Phase I to TRL 4-5. The team will continue development by designing a Variable Conductance Interface (VCI) for protecting water in the Liquid Cooling Garment (LCG) from freezing due to the temperature of the heat sink used by the PCM. The team will also develop system improvements identified during Phase I testing. The PCM will be tested to confirm heat input/temperature performance and cycling capability. The test bed will allow for accurate heat input knowledge, temperature monitoring and cycling capability. The results will be compared to the thermal model to ensure accurate prediction capability for the next phase unit and system implementation. The design description and test results would form the basis of the final report.

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Advanced, Long-Life Cryocooler Technology for Zero-Boil-Off Cryogen Storage

Creare, Inc.

Technical Abstract

Long-life, high-capacity cryocoolers are a critical need for future space systems utilizing stored cryogenics. The cooling requirements for planetary and extraterrestrial exploration missions, Crew Exploration Vehicles, extended-life orbital transfer vehicles, and space depots will range from 10 to 50 W at temperatures between 20 and 120 K. Turbo-Brayton cryocoolers are ideal for these systems because they are lightweight, compact and very efficient at high cooling loads, in addition to their inherent attributes of high reliability; negligible vibration; long, maintenance-free lifetimes; and flexibility in integrating with spacecraft systems and payloads. To date, space-borne turbo-Brayton technology has been developed for modest cooling loads. During the proposed program, Creare will develop an advanced, high efficiency turbine optimized for a high-capacity cryocooler. The advanced turbine will enable a landmark reduction in cryocooler input power and overall cooling system mass. In Phase I, we defined the cryocooler requirements for a particular mission class, developed the conceptual design of a multistage cryocooler to meet the requirements, developed the preliminary design of the advanced turbine and successfully performed proof-of-concept tests on the turbine. During Phase II, we will fabricate the turbine optimized to provide 5-20 W of net refrigeration at 20 K and demonstrate its performance at prototypical operating conditions.

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SAFE-P: System for Assurance of Flight Executable Procedures

SIFT, LLC**Technical Abstract**

NASA operates manned spacecraft according to rigorously-defined standard operating procedures. Unfortunately, operating procedures are often written in different languages. For example, Orion will use automatic procedures written in SCL, the Spacecraft Command Language, while backup manual procedures may be developed in PRL, the Procedure Representation Language. However, procedures developed in different languages may diverge, so that the backup PRL procedures do not operate in the same way as the SCL procedures. This could lead to unintended effects that may range from simply unexpected to inefficient or even catastrophic. We propose to develop the SAFE-P tool, which will use formal model-checking methods to prove that PRL and SCL procedures have the same underlying execution semantics. Our Phase 1 effort validated the effectiveness of our approach; Phase 2 will completely automate the model checking process and integrate with the Procedure Integrated Development Environment (PRIDE). SAFE-P will thus allow procedure authors to easily compare procedures as they are being developed. When differences are found by SAFE-P, they will be highlighted immediately in the PRIDE interface, allowing the operators to either fix problems or annotate the respective procedures to explain the differences. Using SAFE-P, NASA personnel will rapidly and confidently verify that if an automatic SCL program cannot be executed, a backup manual procedure in PRL will be equivalent and safe. Furthermore, as automatic translators are developed to transform procedures in one language into another NASA-relevant language (e.g., Tietronix's current effort to translate PRL into SCL), the SAFE-P tool will provide a critical validation mechanism to double-check the correctness of the translation and highlight areas where the translator makes mistakes (or deliberate approximations that yield different behavior).

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Embedding Procedure Assistance into Mission Control Tools

TRAC Labs, Inc.**Technical Abstract**

Procedures are the accepted means of commanding spacecraft. Procedures encode the operational knowledge of a system as derived from system experts, testing, training and experience. In current Space Shuttle and ISS operations procedures are displayed using applications separate from the applications used to display commands and telemetry. This means that procedures cannot interact with commands and telemetry to help an operator's situation awareness. This leads to slower procedure performance and greater opportunity for errors. TRAC Labs is building on existing NASA Constellation program technology to combine procedures, commanding and telemetry into a single, consistent framework in which to operate space vehicles. Instead of viewing procedures in static displays, flight controllers will have interactive, reconfigurable procedure displays and assistants that can be tailored for specific situations. The displays will have different views tailored to specific operations, including browsing, assigning, editing, executing and monitoring procedures. A procedure executive automates some procedure execution and provides procedure assistance. Automation is always under the control of the flight controller via level of automation feature. Each step or instruction of a procedure can be labeled as manual, automated or consent. This will increase the efficiency of procedure performance and reduce procedure errors.

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An Efficient Parallel SAT Solver Exploiting Multi-Core Environments

Aries Design Automation, LLC

Technical Abstract

The hundreds of stream cores in the latest graphics processors (GPUs), and the possibility to execute non-graphics computations on them, open unprecedented levels of parallelism at a very low cost. In the last 6 years, GPUs had an increasing performance advantage of an order of magnitude relative to x86 CPUs. Furthermore, this performance advantage will continue to increase in the next 20 years because of the scalability of the chip manufacturing processes. The goal of this project is to efficiently exploit the GPU parallelism in order to accelerate the execution of a Boolean Satisfiability (SAT) solver. SAT has a wide range of applications, including formal verification and testing of software and hardware, scheduling and planning, cryptanalysis, and detection of security vulnerabilities and malicious intent in software. We bring a tremendous expertise in SAT solving, formal verification, and solving of Constraint Satisfaction Problems (CSPs) by efficient translation to SAT. In our previous work (done on the expenses of our company) we achieved 2 orders of magnitude speedup in solving Boolean formulas from formal verification of complex pipelined microprocessors, 4 orders of magnitude speedup in SAT-based solving of CSPs, and 8 orders of magnitude speedup in SAT-based routing of optical networks.

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Efficient Integration, Validation and Troubleshooting in Multimodal Distributed Diagnostic Schemes

Qualtech Systems, Inc.

Technical Abstract

In general, development and validation of diagnostic models for complex safety critical systems are time and cost intensive jobs. The proposed Phase-II effort will automate some vital processes essential in developing integrated diagnostic schemes and cost-effective revalidation of the integrated models. The automated processes, resulting from this effort will be incorporated as tools in TEAMS Design and Analytic Platform. For reducing the burden of testing diagnostic models, capability for automatically generating test cases, regression test suites along with the options for their playback will be developed under this effort. Additionally, an option for efficient diagnostics and troubleshooting in multi-mode systems will be introduced in TEAMS via this SBIR effort. To ensure the readiness of the TEAMS tools and options developed through this effort, those will be verified and validated with one or more NASA's ground support systems that are associated with the ARES or Constellation Program Ground Support. Collectively, these achievements will significantly reduce the time and cost in developing and better utilizing large scale fault diagnostic systems using TEAMS.

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Brine Dewatering Using Ultrasonic Nebulization

UMPQUA Research Company**Technical Abstract**

Recovery of water from brine is critically important for future manned space exploration. Resupply of water is prohibitively costly for such extended missions. Water reclamation processes typically recover 90-95% of the water present in wastewater formed by combining urine, hygiene water, and humidity condensate with the remaining concentrated in brine. This concentrated brine contains a significant amount of water, potentially a very valuable resource. The proposed prototype development will recover virtually all of the remaining water using an ultrasonic brine dewatering system (UBDS). In the UBDS process, extremely small nebulized droplets of the brine are created ultrasonically at the brine-air interface. Small droplets enable quicker drying due to their high relative surface area. This is particularly important when drying brines that contain thermally labile materials, which require relatively low temperature drying. The UBDS prototype has no nozzles to become plugged, requires little power, is simple and small, requires minimal astronaut attention and is compatible with continuous, closed cycle operation that can be made gravity independent. The innovative Phase 2 prototype will fulfill the unmet need to significantly improve water loop closure during extended manned missions. The Phase 2 project will provide an automated UBDS prototype that will be delivered to NASA for further testing.

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A Compact, Efficient Pyrolysis/Oxidation System for Solid Waste Resource Recovery in Space

Advanced Fuel Research, Inc.**Technical Abstract**

Pyrolysis processing can be used in near term missions for volume reduction, water recovery (drying), stabilization, and enhanced water and oxygen recovery through thermochemical reactions. For longer term missions, the added benefits include production of fuel, multi-purpose carbon, and reactants for in-situ resource utilization (ISRU). The objective of the Phase I SBIR program was to demonstrate the feasibility of integrating pyrolysis, tar cracking, and oxidation steps into a compact, efficient, system for processing spacecraft solid wastes. This integration, which was based on a microwave pyrolysis/cracking/oxidation unit, has resulted in a significant reduction in energy consumption per gram (~70% when compared to a conventional unit), and an overall reduction in system complexity. These improvements should lead to a lower Equivalent System Mass (ESM) for a full scale system. Under Phase II, a prototype microwave pyrolysis/tar cracking/oxidation unit will be developed in collaboration with ETM Electromatic, Inc., a leading manufacturer of microwave power systems for commercial, space and military markets.

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Multifunctional B/C Fiber Composites for Radiation Shielding

Materials Modification, Inc.**Technical Abstract**

Components of lunar habitat and crew modules in the lunar vehicle are constantly exposed to hazardous space conditions, such as ionizing radiation, electromagnetic interference, orbital debris, and solar flares. The safe functioning of crew and instruments and survivability require effective radiation protection. There is also the desire to reduce the weight of parts in Space missions. In Phase I, Materials Modification Inc. developed a series of novel multifunctional composites using a proprietary high-hydrogen epoxy incorporating boron and carbon fiber layers with enhanced radiation shielding, structural, thermal and electrical properties compared with high density polyethylene (HDPE). Radiation shielding of B/C composites against high-energy neutrons were measured. The boron composites had approximately the same shielding effectiveness as HDPE and aluminum for the energetic neutrons. This is remarkable since the multifunctional properties of these hybrid boron/carbon fiber composites offer so much more than the overall properties of HDPE or Al, especially in the area of lightweight structural applications for aerospace. In Phase II, a series of composite laminates with a range of %B will be fabricated using unidirectional boron fiber and unidirectional carbon fiber in a non-autoclave process. Mechanical properties of the most promising composite compositions, including lamina and laminate properties at cryo temperature, RT, and elevated temperature will be determined. Radiation shielding studies with energetic charged particles such as, protons, heavy ions, and neutrons that would simulate conditions encountered in space will be performed. By the end of the Phase II, we would have manufactured and tested several compositions that provide optimum radiation shielding. We plan to address specific NASA mission requirements with our partners Boeing, Raytheon and Lockheed Martin who have expressed great interest in the results of the Phase I effort.

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Carbon Foam Self-Heated Tooling for Out-of-Autoclave Composites Manufacturing

Touchstone Research Laboratory, Ltd.**Technical Abstract**

Touchstone Research Laboratory, Ltd. (Touchstone) has developed a novel and innovative Out-of-Autoclave (OOA) composites manufacturing process with an electrically heated carbon foam tooling system. Electrically Heated Tooling (EHT) utilizes a coal-based carbon foam (CFOAM^{REG}) core that serves as both the tool substrate and the heating source for a composite part being cured. The tool heating is a result of flowing current through the carbon foam, which results in heating. This approach to self-heated tooling is a potentially enabling technology for manufacturing large composite structures by eliminating the need for autoclaves and large curing ovens, as well as by reducing costs, weight, and improving composite part quality. The overall objective of the NASA Phase 2 program will be to optimize critical factors for thermal uniformity in a CFOAM Electrically Heated Tool (EHT) and to validate the electrically heated cure process with current state-of-the-art OOA materials. The data generated will be used to produce a Scaled Composite Shroud (SCS) cylindrical mandrel EHT that will be designed, fabricated, tested, and used to cure a large composite part without an autoclave or oven. The SCS demonstration tool will be up to an 8' diameter and 12' length mandrel, which will be approximately one-fourth of the scale as a tool necessary for an ARES V composite structure.

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Lunar Navigator - A Miniature, Fully Autonomous, Lunar Navigation, Surveyor, and Range Finder System

Microcosm, Inc.

Technical Abstract

Microcosm will use existing hardware and software from related programs to create a prototype Lunar Navigation Sensor (LNS) early in Phase II, such that most of the effort can be spent in extensive field-testing, making corrections as needed, and critical evaluation of the LNS performance on Earth and projected performance on the Moon. By using NGS survey markers, with centimeter-level position accuracy, as test sites, we expect to create a truth model for both absolute and relative position measurements that is essentially error free (relative to the LNS accuracy), thus allowing very accurate characterization of both random and systematic errors for both absolute and relative position measurements. This unambiguous characterization of the total error will allow validation (or correction) of the navigation error models and assessment of system performance with a high level of confidence. Additionally, the LNS prototype hardware is sufficiently small (roughly shoebox size with a laptop PC for data collection) and easy to set up (put on a tripod over the NGS marker), that it can easily be taken to multiple test locations. Finally, a detailed technology roadmap will be created showing how the TRL 6 LNS can be raised to TRL 9, ready for flight.

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Lightweight Hybrid Ablator Incorporating Aerogel-Filled Open-Cell Foam Structural Insulator, Phase II

Ultramet

Technical Abstract

In previous work for NASA and DoD, Ultramet developed lightweight open-cell foam insulators composed of a carbon or ceramic structural foam skeleton filled with a high temperature nanoscale aerogel insulator. Structural integrity and high insulation behavior have been demonstrated when used in combination with a non-ablating, coated carbon/carbon or ceramic matrix composite outer shell. In Phase I, Ultramet demonstrated the initial feasibility of a foam-reinforced hybrid ablator/aerogel insulator thermal protection system (TPS) in which a portion of the thickness (front face) of a low thermal conductivity structural foam was infiltrated with an ablative material and the remainder of the thickness (back face) was filled with the high temperature aerogel insulator. The potential benefit is a reduction in the ablator mass required to reject the aerothermal heat load. The three-dimensionally interconnected foam reinforcement is anticipated to provide increased char retention relative to alternative fiber and honeycomb reinforcements. The vehicle interface temperature will be controlled by the highly insulating aerogel-filled portion of the foam structure. In Phase II, Ultramet will team with Materials Research & Design (MR&D) for continued thermomechanical design optimization, and ARA Ablatives Laboratory for ablator infiltration of Ultramet structural foam. Performance will be evaluated through high heat flux ablation testing and a demonstration of scaleup potential up to 18" diameter.

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Automation of Health Management, Troubleshooting and Recovery in Lunar Outpost

Qualtech Systems, Inc.

Technical Abstract

The overall Phase-II goal is to develop the technologies and tools that can aid the automation of operation by providing intelligent decision support in situations when a mission plan needs alteration due to an event(s). The effort targets not only developing the algorithms, but also to implement them on QSI's TEAMS platform; this will transition the technologies into a useful tool for the A4O community.

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PM/IDE - An Integrated Development Environment for Planning Models

Stottler Henke Associates, Inc.

Technical Abstract

We propose to develop a planning model integrated development environment (PM/IDE) that will help people construct, review, understand, test, and debug high-quality planning domain models expressed in the Action Notation Modeling Language (ANML) more quickly and effectively. PM/IDE will enable novice modelers to review and understand models more expediently, so they can learn modeling techniques more efficiently. PM/IDE also will enable experienced modelers to review the models of others more quickly, so they can share modeling techniques and best practices. Interactive graphical displays will enable modelers to describe planning domain models under construction and the plans they can generate to domain experts in order to facilitate more efficient knowledge elicitation and model review. Without PM/IDE, ANML modeling will remain a tedious and difficult task that can be carried out only by the small number of people who have the necessary specialized skills and patience. This, in turn, will severely limit the use of ANML-based automated planning systems. During Phase I, we characterized the planning domain modeling task to identify the types of analyses and decisions that modelers carry out and the kinds of information they review and assess. Based on this understanding of the task, we designed and prototyped PM/IDE capabilities and user-system interactions that help people develop ANML models. During Phase 2, we propose to develop a TRL 7 version of PM/IDE. Our design approach draws upon our experience using a top-down, decision-centered software requirements and design process to develop data visualization and decision support systems.

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Robotic Vehicle Proxy Simulation

Energid Technologies**Technical Abstract**

Energid Technologies proposes the development of a digital simulation to replace robotic vehicles in field studies. It will model the dynamics, terrain interaction, sensors, control, communications, and interfaces of a robotic vehicle with the goal of supporting validation and training. The simulation will be very easy to use by simple execution on a networked PC. It will connect to NASA's robot-control frameworks and be easy to configure using a drag-and-drop interface. It will be thorough in its ability to model a range of environments, from terrestrial to lunar, and through its ability to provide accurate sensor and truth data for analysis. It will include simulation of communication latency and bandwidth restrictions. Sensors will be modeled through a powerful plugin interface that supports tying stimulation of new sensor modalities to terrain and objects. The effort will include the development of robot, sensor, and environment models tailored to the simulation of field-study vehicles, and it will emphasize mimicking the network interfaces used by NASA. The proxy simulation will be able to model multiple and disparate robots simultaneously. Energid will implement and deliver a complete, executable system and an underlying C++ software toolkit.

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Fusion of Built in Test (BIT) Technologies with Embeddable Fault Tolerant Techniques for Power System and Drives in Space Exploration

Impact Technologies, LLC**Technical Abstract**

Impact Technologies has proposed development of an effective prognostic and fault accommodation system for critical DC power systems including PV systems. Overall goal for this program is development of techniques that enable power system fault tolerance based on diagnostic features from the solar cells, power bus, and power transistors. After completion of Phase I efforts towards this goal, Impact has achieved substantial and promising results in several technical areas that provide opportunities for maturing PHM tools. The technical areas covered include: 1) solar cell modeling and characterization, 2) power system monitoring, 3) semiconductor device modeling and aging characterization, and 4) application of the leakage current sensing to DC systems. During Phase II, impact will apply and maturing phase I accomplishments to incorporate and embed effective PHM techniques and fault tolerance for power system reliability and extended operation. Impact also plans development of a prototype low cost dynamic leakage current sensor for solar cell and DC power system application. The long-term implications of a successful completion of this program will provide reliability and health management tools for the state-of-the-art technologies, such as advanced power systems based on solar power generation, contributing directly to NASA's ISHM efforts.

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Fast Neutron Dosimeter for the Space Environment

Radiation Monitoring Devices, Inc.**Technical Abstract**

Model calculations and risk assessment estimates indicate that secondary neutrons, with energies ranging between 0.5 to >150 MeV, make a significant contribution to the total absorbed dose received by space crews during long duration space missions [1-3]. Advanced scintillation materials, which exhibit radiation type and mass dependent emission times, coupled to SSPM detectors, provide the optimum volume to payload performance and the ability to easily discriminate between the fraction of dose, which results from secondary neutrons, and that which results from exposure to energetic charged particles and background gamma-rays. The Phase-1 effort successfully characterized the critical components of the proposed dosimeter, specifically, the response of the scintillation material to irradiation by gamma-rays, protons, and neutrons, as well as the performance of the SSPM detector. The Phase-1 modeling studies provide a critical foundation for assessing the anticipated signals in the space radiation environment. The proposed dosimeter would overcome many of the limitations in the current generation of neutron dosimeters, and would provide baseline information on the physics, needed with the information from biological studies, to assess risk in future human-space-exploration missions to the moon and Mars.

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High Efficiency, High Output Plastic Melt Waste Compactor (HEHO-PMWC)

Orbital Technologies Corporation**Technical Abstract**

The innovative High Efficiency, High Output Plastic Melt Waste Compactor (HEHO-PMWC) is a trash dewatering and volume reduction system that uses heat melt compaction to remove nearly 100% of water from trash and reduce the volume by up to 11 times. The HEHO-PMWC system incorporates novel methods to compress the trash, recover water, and remove the resultant plastic tiles. This system requires access to power, data, and cooling interfaces. The system is suitable for recovering water and compacting all trash sources on the ISS. The system has also been designed to recover water from brine solutions produced by primary wastewater processing systems. The HEHO-PMWC works by heating and compressing trash simultaneously to first remove water and then to melt plastic in the trash. The melted plastic encapsulates the trash into a 16 inch square tile, approximately ½ inch thick. The square tile is easier to store than a round tile and is a more effective radiation shield. Variables such as transport vehicle availability, ISS mass, power and space availability, and ISS cooling capabilities were considered. The resulting HEHO-PWMC system, proposed here, was sized to process 3-4 kg of trash per batch while operating three times per day.

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Phenolic Impregnated Carbon Ablator (PICA) Gap Filler for Heat Shield Assemblies

Fiber Materials, Inc.

Technical Abstract

During this program, Fiber Materials, Inc. (FMI) will develop practical methods for preparing Phenolic Impregnated Carbon Ablator (PICA) materials for joining thermal protection system segments and penetrations of the heat shield assembly. Current and future mission flight environments and designs, such as those for Mars Science Laboratory Aeroshell (MSLA) and anticipated for New Frontiers and Mars EDL missions, will be assessed. Capability of the developed solution(s) will address mechanical and thermal robustness, and performance under representative mission heating environment. The Phase 1 program evaluated candidate joining and gap-fill materials, and assessed joining design approaches for cost effective manufacturability and assembly. Material joining design, assembly methodology and material test performance was documented. The Phase 2 program will utilize materials developed during the Phase 1 program to test performance under representative environment(s). A down-selected material-joining approach will result in the design and fabrication of a mission-specific PICA sub-assembly. The prototype sub-assembly will demonstrate assembly methods and the prototype materials will be utilized for characterization and performance testing. The proposed materials, designs and methods are TRL ≤ 3 . It is anticipated that TRL ≥ 6 will be achieved at the conclusion of a successful phase 2 program.

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Computational Tool for Coupled Simulation of Nonequilibrium Hypersonic Flows with Ablation

CFD Research Corporation

Technical Abstract

The goal of this SBIR project is to develop a predictive computational tool for the aerothermal environment around ablation-cooled hypersonic atmospheric entry vehicles. This tool is based on coupling the relevant physics models to the LeMANS code for hypersonic flows and to the MOPAR code for material response, both developed by the University of Michigan. In Phase I of this project, we developed an efficient, high-fidelity 3-D radiation transfer equation (RTE) solver based on the Modified Differential Approximation (MDA). The MDA method was shown to be accurate over at least three orders of magnitude variation in medium optical thickness, typical in entry hypersonic flows. The coupled LeMANS-radiation code was demonstrated for Stardust and IRV2 configurations, while the coupled LeMANS-MOPAR code was validated for the Passive Nostip Technology (PANT) experiment [1], successfully establishing feasibility. In Phase II, the primary focus is to advance the flow and ablation modeling capabilities of the LeMANS/MOPAR codes by including innovative models for: (1) Non-equilibrium surface thermochemistry; (2) Non-equilibrium pyrolysis chemistry; and (3) Non-gray, non-equilibrium radiation. All models will be implemented in a modular manner with particular attention paid to their coupling interfaces to facilitate easy coupling to a computational aerothermodynamics code of interest to NASA such as DPLR. The tool will be validated and applied to ablation-cooled re-entry flow problems relevant to NASA such as the Stardust capsule.

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Multi-Layered Integrated Airframe System

Fiber Materials, Inc.**Technical Abstract**

This proposed Phase II program builds on the Phase I effort addressing NASA's future mission requirements by: 1) developing higher performing TPS materials capable of meeting the demands of multiple severe mission trajectories; and 2) integrating TPS materials with the sub-structure to improve overall robustness and decrease mass. The program's goal is to extend Phenolic Impregnated Carbon Ablator (PICA) and Fiber Materials, Inc. (FMI^{REG}) Integrated Composite Structure (ICS) TPS materials to a broader range of flight heat fluxes and mission performance requirements to address future heatshield design needs. Specific mission enabling improvements sought by NASA that will be developed and/or demonstrated under this Phase II program include: preform/component size, ablation performance, thermal insulation performance, efficient and extendable assembly process, and net-shape preform casting.

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Integrated Inflatable Ballute for Planetary Entry

CFD Research Corporation**Technical Abstract**

CFDRC and TRLA are proposing to develop, design and test a highly scalable, mass-optimized inflatable structure that makes maximum utilization of materials in providing tailored stiffness and rigidity for hypersonic entry vehicles. The proposed inflatable structure is a hybrid pressure restraint vessel employing an impervious cloth-reinforced barrier structure enveloped by an integrated array of high-tenacity tendons. The external grid of cordage tendons provides mass- and load pathway-optimized containment of the structure's global pressure loads. In Phase I, the conceptual model was designed and the materials were evaluated for their stiffness. The feasibility of the model was demonstrated for typical Mars trajectory point. Phase II efforts will focus on fabricating and testing a prototype of the proposed inflatable structure to validate the design robustness and capability for larger payload masses. Pre and post testing multidisciplinary integrated fluid-structure-thermal simulations will be conducted to provide insight into the aerodynamic, material stress and dynamic characteristics of the model and to verify/optimize the developed design. Wind tunnel testing as well as dynamic aerostructural simulations will be conducted to verify the stability of the model. The developed inflatable concept will be fabricated complete with flexible TPS, multiple protection layers and sensors and will be tested to demonstrate the prototype folding, packaging, and deployment.

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Ionomer-membrane Water Processor System Design and EDU Demonstration

Paragon Space Development Corporation

Technical Abstract

a. Paragon Space Development Corporation (Paragon) proposes to continue our investigation into the use of microporous-ionomer membrane technology to improve the robustness and effectiveness and simplify water recovery processes for space applications. Improved robustness and effectiveness will be evident through (1) reduced loading on the downstream post processor due to the ionomer's unique property of selective permeability, (2) near complete removal of water from wastewater, and (3) inclusion of a backup barrier between the retentate and permeate. The technology offers simplification over existing technology through (1) a lower dependency on moving parts, and (2) integrated capture of wastewater solutes for disposal. Phase 1 testing showed that 99% of the contaminants in concentrated pretreated urine ersatz were removed by the proposed technology and virtually complete dewatering of the brine was achieved in a configuration that would appear to be insensitive to gravity and orientation. As the technology is fully developed, it can be inserted into existing and/or developing water recovery system architectures to increase water recovery rates beyond that currently available to date. The application of this technology for spacecraft water reclamation will be referenced as IWP (Ionomer-membrane Water Processor).

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TBA- Contract Under Negotiation

Ontological Models to Support Planning Operations

TRAC Labs, Inc.

Technical Abstract

Automation and autonomy technologies, such as automated planning software, are key elements in realizing the vision for space exploration. However, the major stumbling block to realizing the widespread use of automation tools for operations is capturing and maintaining the domain models -- the object types and subtypes, relationships among them and operational constraints -- needed to support such techniques. Our success in Phase 1 showed that it is possible for subject matter experts (SMEs) to author ISS model information to produce a consistent model useful for planning, scheduling and procedure execution. In this Phase 2 proposal we aim to fully develop the authoring and data integration portions of our design and to integrate the resulting models with our interactive planning aid for flight controllers. The benefits for NASA operations are that the resulting modeling framework will 1) make available a consistent domain model that need not be reproduced for each automation project, unify the often disparate sources of EVA and Core Systems information, provide for rapid update of ISS configuration information, thus allowing automation applications to provide results based on the most recent data, provide a consistent view of the domain so as to minimize error in authoring procedural data.

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TBA- Contract Under Negotiation

Automation for Vehicle and Crew Operations

Qualtech Systems**Technical Abstract**

Space missions are immensely costly endeavor – fault free function of the hardware and software used therein are highly critical to mission success. Being highly complex, manual intervention in operation, troubleshooting, and health management related areas are labor intensive and time consuming. On top of that with time the complexities of the systems are increasing, and the performance and availability requirements are become even more stringent. In the face of this situation, automation technologies are increasingly looked upon to perform critical tasks in short time, without manual intervention (or with minimal intervention) in error-free manner. Qualtech Systems, Inc., in collaboration with TRAC Labs, Inc., proposes developing novel capabilities in the areas of health management, providing information for health and capability-related situational awareness, acquisition of data from onboard systems, and generating and invoking procedures for troubleshooting, restoration of operation, and/or initiating safety assurance processes.

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Graded Density Carbon Bonded Carbon Fiber (CBCF) Preforms for Lightweight Ablative Thermal Protection Systems (TPS)

Fiber Materials, Inc.**Technical Abstract**

FMI has developed graded density CBCF preforms for graded density phenolic impregnated carbon ablator (PICA) material to meet NASA's future exploration mission requirements for higher performance ablative TPS. Graded Preform PICA (GPP) will be achieved by the continued development of lightweight, graded density carbon preforms which will decrease the overall areal mass of the resulting TPS material while enhancing its thermal performance capability. The preform material designed to achieve this goal is comprised of a more mechanically robust, ablating outer layer and a lower weight, lower thermal conductivity inner layer than state-of-the-art PICA material. The ablative outer layer and thermal inner layer will be integrated in a continuously cast, monolithic material with equivalent capability for resin impregnation and conversion to PICA as the baseline existing preform material (FiberForm®). During the proposed Phase II program, FMI will continue to develop its capability to produce graded density preform material to achieve TPS areal mass reductions estimated between 17-25% relative to PICA with the goal of improving ablation performance. The developed preform materials will be converted to GPP and then characterized mechanically, thermally, and tested for ablation performance. In addition to providing a pathway for these enhancements to tile acreage PICA TPS ablator material, FMI will incorporate the developed processing methodology to produce near net-shaped cast PICA TPS material preforms with a reduced density gradient compared to baseline manufacturing techniques.

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Compact, Ultrasensitive Formaldehyde Monitor

Novawave Technologies

Technical Abstract

The Small Business Innovative Research Phase II proposal seeks to develop a compact UV laser based sensor for Earth science and planetary atmosphere exploration. The device will be capable of measuring formaldehyde in real-time at ultra-trace levels. The sensor is based on a revolutionary, single frequency tunable UV fiber laser that was successfully demonstrated for the first time during Phase I. This laser was mated with a detection cell and high fidelity formaldehyde spectra were obtained. The Phase II sensor will be compact and capable of detecting formaldehyde at ppt levels, and may be capable of simultaneously detecting NO₂, an important pollutant.

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Airborne Wide Area Imager for Wildfire Mapping and Detection

Xiomas Technologies

Technical Abstract

An autonomous airborne imaging system for earth science research, disaster response, and fire detection is proposed. The primary goal is to improve information to researchers and operations personnel. By operating autonomously and with higher spatial resolution, the system will deliver a 3X to 4X reduction in operating costs compared to current systems. The system uses a two color Quantum Well Infrared Photo detector (QWIP) to improve the accuracy of energy release from wildfires, thereby improving our understanding of the carbon cycle. The system includes a multi-sensor step-stare imager, position and attitude sensor, data communications link, and a data processing system with; feature extraction (such as fire detection), image geo-coding, and image compression. The sensor head is an innovative design combining high resolution framing devices (cameras) with a step-stare scanning mirror. This configuration results in high spatial resolution imagery and wide area coverage. The design of the sensor head is flexible allowing for a variety of imagers including; visible and IR cameras and/or hyperspectral sensors. We envision several versions of the instrument, one weighing around 75 pounds and a smaller version weighing less than 15 pounds.

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Multispectral Particle Absorption Monitor

Aerodyne Research, Inc.

Technical Abstract

This Small Business Innovation Research Phase II project concerns the development of a multi-wavelength monitor that will provide rapid, real-time measurement of the average aerosol absorption coefficient in a parcel of sample air. This monitor will employ Aerodyne's patented Cavity Attenuated Phase Shift (CAPS) technology in order to produce a far simpler, smaller, lower cost alternative to more traditional instruments with no loss in sensitivity or accuracy. A unique property of the proposed instrument is that it requires little or no calibration. The Phase II project entails construction a field-ready prototype and deploying the sensor on various field missions undertaken by Aerodyne's particle measurement research group. Aerosol particles affect the radiative balance of the earth directly, by scattering and absorbing solar and terrestrial radiation, and indirectly, by acting as cloud condensation nuclei. The atmospheric loading of aerosols generated through human activities can exert an influence on the earth's radiation budget comparable in magnitude with greenhouse gases. The uncertainties in the current understanding of aerosol direct and indirect forcing limit the ability to quantify human influences on climate change.

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step_SATdb, An Open Source Based Satellite Design Data
Architecture with API Design and Management Plugins

sci_zone

Technical Abstract

Satellite design encompasses a multitude of steps from concept to flight, which can take several years, depending on the scope, requirements and budget of the mission. The process also requires a wide range of design and management tools, with limited consistency and data interchange capability. Detailing the relationships between the satellite configuration (components and interrelationships), inventory control systems, life cycle management, design, analysis and test data is extremely difficult at best. No tool exists that meets these needs for the general satellite design, system engineering and integration process. Sci_Zone has begun development of our innovative Satellite Design Automation architecture QuickSATTM, in conjunction with our step_SATdb open database architecture to meet this need. step_SATdb seamlessly integrates existing detail design tools with QuickSATTM, as well as databases tracking requirements, hardware and software components and payloads in inventory, with the final configuration of the satellite. QuickSATTM, provides for not only rapid design, via design wizards and integration to existing design tools, but will provide coherency between a range of applications and data sets. step_SATdb stores and distributes supporting satellite design, configuration, mission, support and test data from a centralized database server and can distribute the data across multiple platforms and via the internet.

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Low-Cost Suite of COTS GNC Sensors for Precision Lunar Lander **Stellar Exploration, Inc.**

Technical Abstract

We are proposing to exploit (in an innovative way) existing, readily available, GNC sensors for the purpose of precision lunar landing. Majority of previous lunar lander concepts with the precision/pinpoint landing capability required expensive and risky development of new GNC and landing sensors (scanning lidars, multi-beam mm-ww radar, etc.). Our proposed alternative consists solely of existing and low-cost sensors that synergistically leverage each capability and compensate for individual sensor weaknesses. For example, we can use a simple single-beam low-frequency radar altimeter (available at low-cost off-the-shelf, and proven on several Mars lander missions). The low-frequency radar can meet the maximum slant range requirements much easier than the mm-wave sensor but it does not have the adequate multiple narrow beam capability of the Apollo LM or Viking lander radar. However, the optical descent imaging measurement (using DSMAC-type sensor) can supplement the single beam radar measurement and obtain the same information about the complete state vector. There are several similar concepts implemented in this sensor suite of complementing strengths and weakness of individual sensors.

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Innovative Applications of DoD Propulsion Technology for Low-Cost Satellite Missions

Stellar Exploration, Inc.

Technical Abstract

We are proposing to leverage the Missile Defense Agency investments in high-performance propulsion systems for low-cost space missions with large Dv requirements, for example, a soft lunar lander. This design concept exploits a core set of hardware developed under past and current Department of Defense (DoD) investments. The propulsion system concepts under consideration are from the DoD's Missile Defense Kinetic Kill Vehicle programs such as EKV, THAAD, ASAT and LEAP. These are bipropellant, storable and hypergolic system that use high-performance propellants (MMH/NTO). This subtopic is seeking technologies with the superior performance for orbital control, for on-orbit applications including storage capability and propulsion. This propulsion system should allow transfers from LEO or GTO to lunar orbit or similar destinations. These missions have in common the substantial Dv propulsion requirements that cannot be met with the existing flown propulsion systems on current small spacecraft missions (for example, SNAP-1, Cubesats, Orbcomm or similar missions). Our proposed solutions offers that capability at an affordable but credible cost.

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Nitrous Oxide Liquid Injection Thrust Vector
Control System Testing

Whittinghill Aerospace, LLC

Technical Abstract

A Nitrous Oxide-fed Liquid Thrust Vector Control system is proposed as an efficient method for vehicle attitude control during powered flight. Pulled from a N₂O main propulsion system oxidizer tank, it features system simplicity, no toxicity, room temperature storability, high system mass fraction and superior performance due to its exothermic decomposition characteristics, answering the need for innovative attitude control technologies. A continuing series of 1,000 lb thrust hybrid rocket motor tests are proposed to characterize N₂O's Side Specific Impulse as a function of thrust vectoring angle, as well as a series of 4,000 lb thrust motor firings culminating in a closed-loop Guidance Navigation and Control Hardware-In-The-Loop test in a vertical stand. At the conclusion of Phase 2, the technology will be ready for development into an upper stage as an integrated main propulsion Thrust Vector Control (TVC) /Attitude Control System for a small launch vehicle, or as a separate TVC system for any solid, liquid or hybrid powered vehicle.

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Pulsed Electrogasdynamic Thruster for Attitude
Control and Orbit Maneuver

Physical Sciences, Inc.

Technical Abstract

In the Phase I program we successfully demonstrated the feasibility of the Pulsed ElectroGasdynamic (PEG) thruster for attitude control and orbital maneuvering. In this thruster, propellant gas is introduced into the thrust nozzle through a fast acting gas valve where a short, high voltage pulse is applied to break down and heat the propellant gas. The heated gas expands in the nozzle generating a high impulse (~mN-s per pulse) at a high specific thrust (120 gN-s/joule). The specific impulse (I_{sp}) will be in the range of 500~1500 sec. This process can be repeated at a frequency to meet the spacecraft thrust requirements. The thrust generating mechanism of the proposed thruster is gasdynamic expansion, not magnetohydrodynamic interaction. The proposed thruster is different from the conventional pulsed electrothermal thruster in that the joule heating of the propellant takes place as the propellant gas expands through the divergent nozzle, thereby eliminating the heat and momentum losses at the nozzle throat. Our Phase II objectives are: (i) develop an engineering model; and (ii) develop a proto-flight model of the proposed thruster system.

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Virtual Satellite Integration Environment

Advatech Pacific, Inc.**Technical Abstract**

An integrated environment for rapid design studies of small satellite missions will be developed. This environment will be designed to streamline processes at the NASA Ames Mission Design Center. Several key concepts are introduced. The proposed environment introduces modern Product Data Management and Product Lifecycle Management (PDM/PLM) tools and processes to satellite mission design. Specifically, the notion of product structure, or bill of material (BOM), is expanded to a simulation BOM, or SBOM, with the capability to manage engineering analysis data, files and processes in the context of a product, in this case satellite mission. This approach constitutes a significant step beyond mere document management, which limits the traceability of which model of which analysis belongs to which version of the geometry or other analysis. It is a key enabler for model re-use. A Linked Model Environment (LME), i.e. an environment where all engineering analysis models are associatively linked, which was developed concurrently in the commercial aerospace and automotive industry, will be extended to satellite mission design. This environment significantly reduces the amount of manual intervention engineers have to perform to translate information from one simulation tool to another. The concept of digital mockup (DMU), which typically addresses form and fit of components in an assembly, is expanded to include function, such that the inclusion of components in a satellite assembly that are functionally incompatible is rejected. Repetitive-iterative engineering tasks will be automated with the help of an integration framework tool which automates the execution of a sequence of codes and provides the capability to wrap drivers like optimizers or quality engineering tools around an automated analysis workflow.

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Open System of Agile Ground Stations

Espace Inc.**Technical Abstract**

The Phase I effort demonstrated, through actual development and tests with a spacecraft system, the technical and programmatic feasibility of developing, within the SBIR phase II program, the prototype of an innovative and low-cost Open System of Agile Ground Stations using the new commercial Software Defined Radio (SDR) technology. The prototype agile stations will operate in a wide band used by NASA and other science and technology satellites and will be able to switch between communications frequencies, modes and data protocols, in real time, to service multiple satellites. The stations will be remotely programmable to store portfolios of satellite applications, and will switch between applications on demand from the largely automatized Ground Station Management and Maintenance Center (GSMMC). Multiple station sites will provide a high level of back-up capability and link opportunities at up to 3.5Mbps/s and will eliminate down-times. The GSMMC will interface with the different satellite Mission Operation Centers, and oversee the scheduling and programming of the station system. The prototype system will be implemented on the existing HETE-2 network of three stations, opening that system to service multiple missions at very low cost, while significantly enhancing its capabilities and performance.

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Self-Calibrating Greenhouse Gas Balloon-Borne Sensor

Southwest Sciences, Inc.

Technical Abstract

Understanding the sources and sinks of carbon dioxide and other greenhouse gases has been recognized as critical to predicting climate change and global warming. A variety of research studies funded by DOE, NSF, NASA and NOAA to measure the fluxes and fluctuations of CO₂ profiles throughout the troposphere and lower stratosphere have provided a great deal of useful information, but the instrumentation used has been restricted to airplane or large stratospheric-type balloon gondola platforms where a few measurements are very expensive. We propose a new approach where low cost, extensive measurement campaigns can be made using standard meteorological balloons. In this SBIR program, Southwest Sciences is developing a lightweight, inexpensive greenhouse gas sensor suitable for balloon sonde measurements. Using a novel measurement technique, this sensor will provide dry air mixing ratios of CO₂ without the need for concurrent measurements of temperature, pressure or moisture. The Phase 1 research successfully demonstrated the viability of this approach and in Phase 2, a prototype sensor will be built and field tested in a series of balloon-sonde flights.

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A Miniaturized UV/VIS/IR Hyperspectral Radiometer for Autonomous Airborne and Underwater Imaging Spectroscopy of Coastal and Oceanic Environments

Opto-Knowledge Systems, Inc. (OKSI)

Technical Abstract

The AquaScan, a miniaturized UV/VIS/NIR hyperspectral imager will be built for deployment on a UAV or small manned aircraft for ocean coastal remote sensing applications. The hyperspectral system includes a data acquisition system with remote operation capability providing a real-time waterfall display of the hyperspectral scans. OKSI teamed with Scripps Institution of Oceanography to define and design a sensor that explicitly meets the performance requirements needed for ocean remote sensing of coastal regions, but can also be used for terrestrial remote sensing. Specifically, some key requirements called for: 1) high spatial resolution (< 1 meter), 2) high spectral resolution (< 10 nm), UV \square NIR coverage (300 \square 1000 nm), 4) high sensitivity for low reflectivity of ocean surfaces, 5) provide simultaneous downwelling solar radiation measurements, and 6) allow for operating mode that avoids specular reflections off ocean surface. The AquaScan design was completed during the Phase I effort. During Phase II the sensor will be manufactured, tested, calibrated, and prepared for flight testing. The system will then be demonstrated during several airborne tests off the Southern California coast. The tests will include measurements of spatially/spectrally unique ocean phenomena including red tide blooms and river plume run-offs after heavy rain storms. Coordinated ship-based remote sensing and in situ measurements will take place concurrently with the newly developed miniature UV/VIS/NIR airborne measurements. The ship-based measurements will serve as ground truth for validation/verification. In addition, OKSI will attempt to coordinate data collections with satellite passes (e.g., MODIS, MERIS, SeaWiFS). Comparison with satellite data will serve as validation and demonstration of the capability to support future satellite programs (e.g., GEO-CAPE).

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Laser Ablation - Optical Cavity Isotopic Spectrometer (LAOCIS)

Applied Spectra, Inc.**Technical Abstract**

We propose the detailed conceptual development of a device for analyzing key isotopic composition in surface materials without sample preparation. We will combine absorption spectroscopy with laser induced vaporization of solid samples for high-resolution isotopic measurements. An immediate focus is on Mars but our concept is also highly germane to other applications relevant to bio- and geochemical objectives. We will evaluate accuracy, sensitivity, and resolution of our technology for isotopic detection of the key elements associated with signs of life (C, S, H, O) in solid materials. All essential design components of the proposed analyzer have been separately developed and demonstrated in very compact form for other applications. We will demonstrate the overall performance of the proposed technique and build a breadboard prototype instrument. Commercial systems based on the Phase II prototype will be developed and marketed during Phase III.

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Lab on a Chip LCVR Polarimeter for Exploration of Life Signatures

Intelligent Optical Systems, Inc.**Technical Abstract**

Life on Earth is unique in many ways; one of its great mysteries is that the building blocks of life on Earth (amino acids, nucleotides, sugars) are all chiral. One optical isomer of each amino acid or nucleic acid was selected by evolution. In our pursuit of finding life on Mars and beyond (Triton, Europa, etc.), it is likely that one of the clues to extant or extinct life could be the detection of non-racemic chiral molecules. This proposal describes the development of a highly miniaturized and ultrasensitive lab-on-a-chip polarimeter that will meet the NASA need to measure chirality in very small volumes of samples at very high sensitivity. The proposal builds on a novel technology that is based on a proprietary design, in which a modulated liquid crystal variable retarder (LCVR) enhances sensitivity and reduces size without sacrificing performance. This detection principle with a long-path-length microfluidic flow cell allows for the measurement of chirality in microliter volumes of samples. The Phase I effort has conclusively demonstrated the technical feasibility of the detection principle. A miniaturized polarimeter with microfluidic flow cell was designed and fabricated. The polarimeter was calibrated and tested with samples. In Phase II, we will build, fully characterize, and deliver a miniature polarimeter with optimized performance, enhanced mechanical stability, and integrated fluid handling capability. The primary goals are to further improve the polarimeter's sensitivity, accuracy, size, weight, reproducibility, measurement speed, and power needs, conduct extensive testing, and deliver a robust prototype, engineering drawings, software, and test results to NASA.

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Deep UV Raman/Fluorescence (DUV-RF) Stand-Off Sensor for Lunar Science

Photon Systems

Technical Abstract

This Phase II proposal is to develop a miniature, low power consumption, fused deep UV Raman and native fluorescence (DUV-RF) 1 meter stand-off sensor. The proposed instrument has an enhanced ability to measure the spatial distribution of chemical species containing C/N/H/O/S/Cl, and water, ice, and hydrated-minerals on a 1-5 mm spatial scale enabled by a novel wide-aperture, high-sensitivity ultraminiature UV Raman spectrometer. Raman spectroscopy is a non-contact, non-destructive, method of identifying unknown materials without sample acquisition or processing; ideal for in-situ rovers. However traditional Raman instruments are plagued with fluorescence backgrounds, require sample altering, high-powered lasers, and require the use fiber optics; an instrument design with operational constraints and high power requirements. Our innovative instrument design incorporates our deep UV lasers for fiberless resonance Raman spectroscopy in a fluorescence free zone where resonance effects lead to enhancements by > 2-3 orders of magnitude over 532 and 785 nm systems and can be coupled to native fluorescence for ppt detection of aromatic organics compounds. The New Frontiers has placed a South pole-Aitken Basin sample return as a future mission scenario. The enhanced detection capabilities of DUV-RF can be used to provide an understanding of organics and water distribution in the lunar regolith.

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X-Ray Diffraction and Fluorescence Instrument for Mineralogical Analysis at the Lunar Surface

inXitu, Inc.

Technical Abstract

We propose to develop LUNA, a compact and lightweight X-Ray Diffraction (XRD) / X-Ray Fluorescence (XRF) instrument for mineralogical analysis of regolith, rock samples and dust, in lunar surface exploration. LUNA is based from the concept of CheMin, the XRD/XRF instrument of MSL, but is redesigned to provide a more compact unit at much reduced costs. Many details of LUNA derive from the designs of a small portable XRD/XRF instruments developed and marketed by inXitu. Bringing LUNA to TRL 6-7 is possible within the scope of this Phase II because key components have been or are being developed. Phase 2 addresses the missing critical subsystems: a low-cost flight-qualifiable X-ray CCD, and flight-qualifiable electronics to drive the detector and control the instrument. LUNA is not frozen in a particular geometry or mechanical implementation, it is meant to be flexible to answer the specific needs of any lunar mission. Transmission or reflection geometries are possible as demonstrated by inXitu's commercial instruments. Phase 2 will demonstrate a reflection version of LUNA operating under vacuum. This work leverages on the extensive experience of the PI and the company with XRD-XRF instrumentation in terrestrial and planetary applications.

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A Modular Minimum Cost Launch System for Nano-Satellites

Whittinghill Aerospace, LLC**Technical Abstract**

As minimum cost will be required for a dedicated Nano-Sat Launch Vehicle, a parallel staged, highly modular vehicle architecture is proposed for development. The principal advantage of a modular architecture for this size of vehicle is the single propulsion development for the boost stages at a relatively small scale. This approach drastically shortens development timelines and cost. A candidate launch vehicle with a cluster of seven identical modules would light 4 modules for the first stage, 2 for the second, 1 for the third, and fire 1 small spinning Apogee Kick Motor (AKM) for the fourth. Whittinghill Aerospace (WASP) proposes to refine the Phase 1 design of an all-composite, N₂O-fed Hybrid Rocket Motor (HRM) propelled, 25 kg to LEO launcher. WASP will then build and fire the AKM, build and fire the core module HRM, then launch the full-scale core module as an unguided sounding rocket from a commercial range. At the conclusion of Phase 2, the technology will be at a TRL level of 6.

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TBA- Contract Under Negotiation

ESPA Based Secondary Payload Orbit Maneuvering System

Busek Co., Inc.**Technical Abstract**

Busek proposes to develop an integrated propulsion, power, ACS, (ProPACS) system for micro-spacecraft deployed from the ESPA ring secondary payload ports. The standardized ProPACS system integrates the essential elements needed for highly capable micro-spacecraft bus including; 1) 600 W Hall effect thruster system for primary propulsion, 2) Xe cold gas thrusters for propulsive ACS, 3) articulated solar array, batteries and power management and distribution (PMAD) system with steady state power of 700W available to the payload when propulsion is off and 4) an integral structure that supports the payload and a LightBand separation mechanism for the ESPA ring. The ProPACS can provide over 1,800 m/sec deltaV to a 181 kg spacecraft with a 80kg payload. In Phase 1 ProPACS system architecture design was completed and all major components were identified. Mass, power, data budgets were developed and major interfaces were specified. Phase 2 focus will be on the ProPACS elements with lower TRL to achieve system wide TRL6 at the end of the program. The thruster will be advanced to near flight level, two PMAD systems will be evaluated and one selected and the ProPACS integral structure supporting the payload and separation ring will be designed and built.

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Thermal Control Nano-Sat

Eclipse Energy Systems, Inc.

Technical Abstract

Based on successful space testing onboard the Midstar1 satellite, Eclipse Electrochromics have been identified by a number of organizations as well as NASA as a high interest technology. For nanosats, the critical design challenge is achieving autonomous control of the EclipseVEDsTM for spacecraft thermal self regulation without the need for human intervention. To achieve this goal, Eclipse employed EclipseVEDTM technology and demonstrated the capacity to have automated control thermal systems capable of in-flight thermal regulation of a cubesat or other small satellite. In Phase II, Eclipse will build a complete multi-panel cubesat and work with NASA to lab test a completely functional prototype and review the capacity to utilize the ECDs concurrently with photovoltaics.

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TBA- Contract Under Negotiation

Small Sat Analysis Laboratory

Cybernet Systems Corporation

Technical Abstract

Develop Small Satellite Analysis Laboratory (SatLab): A simulation-of-simulations framework to integrate component and engineering simulations into a single larger simulation capable of full satellite system trade analysis and optimization, in order to reduce the cost and increase the quality of design and development of new small satellites and space vehicles, and test system upgrades and modifications on other space systems.

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Small Space Platform Enhanced Internet Protocol Stack Device

Broadata Communications, Inc.**Technical Abstract**

Wireless communication of small, nano and micro satellites will play a vital role to NASA mission and marketability of the satellite. The use of an Internet-based protocol, especially TCP/IP, can provide seamless network command and control continuity between terrestrial and space-based platforms and environments, as well as between distributed ground and space stations. However, long propagation and/or large transmission errors can significantly degrade current TCP/IP performance. In addition, current TCP is too complex to fit in a small footprint, which is required in microsats and nanosats. To address this NASA/ARC need for wireless networking technologies for small launch vehicles, Broadata Communications, Inc. proposes to develop a Small Space Platform Internet Protocol Stack with Space-Enhanced TCP technology (or SSP IP & TCP in short) to dramatically increase TCP/IP performance (20 times improvements over standard TCP/IP was demonstrated in Phase I) and enable the use of TCP/IP for processor-footprint constrained spacecraft in NASA missions. The overall goal of this Phase II project is to further develop the SSP IP & TCP technology, and to produce a full-scale, highly-optimized, IP embeddable SSP IP & TCP prototype system for placement in NASA networks with micro- or nano-satellite platforms. Our Phase II work plan is designed to complete SSP IP & TCP development and to produce: (a) a miniature, nanosat integrateable, standalone embedded network system module that provides all SSP IP & TCP functionalities and can directly meet NASA needs and resource-constraint integration requirements, and (b) a full-scale SSP IP & TCP software package that supports multiple network communication interfaces and provides automated installation for Linux or Windows operation systems.

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Enabling Technology for Small Satellite Launch

Design_Net Engineering LLC**Technical Abstract**

Access to space for Small Satellites is enabled by the use of excess launch capacity on existing launch vehicles. A range of sizes, form factors and masses of small sats need to be accommodated. An integration process that minimizes programmatic/technical risk to the primary, allows "late flow" integration and predictable cost/schedule for the secondary enables regular and cost-effective access. The integration process proceeds smoothly when the right adapter accommodates the secondary in a seamless way. Design_Net, with our commercialization partner SpaceAvailable Inc. has designed a family of adapters that meet these criteria and one has been selected by NASA to complete development for targeted NASA rideshare opportunities. We are also currently working with United Launch Alliance (ULA) for a broader class of rideshare accommodations, and development of interfaces that allow late access on Evolved Expendable Launch Vehicles (EELV)s. Design_Net will continue, via this SBIR Phase 2, to develop the selected adapter to a structurally tested engineering model. This adapter can accommodate everything from 6u and 12u carriers to full up "ORS class" (800lb) small satellites and is applicable to Minotaur IV, Falcon 9 and Taurus 2.

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Atmospheric Aerosol Analysis using Lightweight Mini GC

Seacoast Science, Inc.

Technical Abstract

The major components of manmade aerosols are created by the burning of coal and oil. Aerosols are recognized to significantly impact the climate through their effects on solar and terrestrial radiation. Accurate speciation and measurement of aerosol composition is an important first step in understanding and managing these pollutants. This Phase II proposal continues development of a small, portable, detection system specifically for the collection, speciation and identification of gas phase and aerosolized organics. This Mini Gas Chromatograph collects samples and operates without the need for compressed-bottled gas by using Seacoast's proprietary chemicapacitive sensor array and commercial sensors with a preconcentration/chromatography system, combining selectivity from a diverse sensor array with a miniature sampling system for amplified sensitivity. Specific components are: 1) sample preconcentrator/collector capable of being heated quickly, 2) capillary column to separate the chemicals released from the preconcentrator and provide selectivity, 3) the chemical sensor array containing Seacoast's chemoselective microcapacitors and metal-oxide-based detectors, 4) integrated user interface. In Phase I Seacoast demonstrated that the system is capable of analyzing gas-phase and aerosolized volatile organics. In Phase II we propose to further develop the system's capabilities with a focus on improving sensitivity and collection efficiency.

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An Infrared Fiber-Optic Raman Sensor for Field Detecting of Organic Biomarkers

Crystal Research, Inc.

Technical Abstract

The search for organics on Mars remains a key objective for future missions. However current instruments for detailed organic analysis require complex sample handling and can process only a limited number of samples. To allow for rapid sample characterization, the in situ non-destructive Raman detection technique is a highly desirable sensing tool for both qualitative and quantitative analysis. However, current Raman systems deployed in the field are inadequate due to deleterious fluorescence interference. Fluorescence is often several orders of magnitude more intense than Raman scattering signals and its broad structures spectrum could be difficult to remove from Raman spectra. We propose to develop a rover-mounted infrared fiber-optic Raman sensor that can eliminate fluorescence with significantly improved Raman sensitivity for fast field detections. The infrared fiber-optic Raman sensor is based on recent technology advances in fiber lasers, fiber optic Raman probes and infrared detector arrays. Innovative infrared fiber-optic Raman sensor enables highly sensitive fluorescence-free Raman analysis and offers flexible remote detection, so that the field spectral sensor's overall performance would be intact and extremely flexible for planetary missions. We will deliver a rover-mounted infrared fiber-optic Raman sensor to NASA at the end of Phase II program.

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Dropsonde System for Unmanned Aerial Vehicles

Anasphere, Inc.**Technical Abstract**

A small, modular dropsonde launcher is being developed for Unmanned Aerial Vehicles (UAVs). Some critical measurement needs can only be satisfied by in-situ measurements. Key examples of such measurements include detailed atmospheric profiles, point meteorological conditions on the surface, and in-situ measurements for calibration and validation of remote sensing systems. Phase I work saw the design and fabrication of a new type of dropsonde with a novel form factor and the associated launcher. The system was installed in a representative UAV nose. System components were successfully tested. Phase II will involve finalizing the launcher and dropsonde designs, developing the associated control and data handling system, building and testing the integrated system, and finally conducting test flights on a UAV. The ultimate result of the project will be a dropsonde system that can be fitted to many NASA UAVs, including small UAVs, and enable them to gather in-situ atmospheric profiles and surface measurements using dropsondes. The Phase II entry TRL is 5; the expected exit TRL is 8.

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Very Dense High Speed 3u VPX Memory and
Processing Space Systems**SEAKR Engineering, Inc.****Technical Abstract**

While VPX shows promise as an open standard COTS computing and memory platform, there are several challenges that must be overcome to migrate the technology for a space application. For the Phase I SBIR, SEAKR investigated the 3u VPX architecture for the space environment for advanced memory and processing systems. The SBIR investigation focused on researching innovative switch fabric architectures, identifying and qualifying the building blocks for a space qualified VPX system, and addressed some of the challenges associated with VPX flash memory modules. The areas of innovation that have been addressed are outlined below: Research and evaluate the basic building blocks required for a high speed switch VPX architecture; Explore advanced EDAC and innovative wear leveling techniques for commercially upscreened flash memory for space applications; Evaluate different techniques for very high speed flash memory access rates. The Phase II SBIR will build on the Phase I study to produce a deliverable engineering model of a 3U VPX flash memory module.

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Reaction Wheel with Embedded MEMS IMU
Milli Sensor Systems and Actuators, Inc.

Technical Abstract

Reaction wheels are used to stabilize satellites and to slew their orientation from object to object with precision and accuracy by varying the rotational speed of the wheels. Three or four wheels are usually used with three of them aligned along orthogonal axes. The degree to which pointing stability is achieved depends on the stability of the wheels' angular momentum vectors while spinning, which can be affected by static and dynamic unbalance contributions and other wheel construction issues. With the smaller satellites, requiring smaller wheels, the stability of the wheels will be even more challenging as the uncertainty of construction is likely to remain the same. To stabilize the smaller reaction wheels we propose to integrate a Sensor Chip containing MEMS gyroscopes and accelerometers with each reaction wheel. This allows direct measurement of the wheel motions for fine-tuning its operation. The improved wheel then becomes a means for improving IMU sensor stability for precision pointing and slewing from object to object.

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TBA- Contract Under Negotiation

TORC-SP: High Torque, Low Jitter Scissored-Pair
CMG Technology
Honeybee Robotics Ltd.

Technical Abstract

NASA sees an increasing role in the near future for small satellites in the 5-100 kg size range. A potentially disruptive technology, small satellites are being eyed as platforms for the rapid demonstration of new technologies and important science missions. Currently, small satellite platforms struggle to balance the three critical tasks of collecting enough power, acquiring data and downlinking that data to ground stations in a way that maximizes mission return. For these small platforms, which usually do not benefit from steer-able solar arrays or gimbaled antennas and instruments, optimally balancing these three tasks strongly depends on the satellite's attitude control agility. Spacecraft agility has to do with rapid retargeting, fast transient settling and low jitter pointing control. Dr. Bong Wie, renowned spacecraft attitude control expert and Professor of Aerospace Engineering at Iowa State University, stated that ultimately the "measure of an agile satellite attitude control system is its ability to collect the maximum data from an area on the Earth that is rich in data-collection opportunities". A logical corollary following from this statement would be that to maximize satellite data-collection, system designers should look to increase the satellite's agility. Furthermore, in addition to data-collection, the other two critical tasks of power collection and data downlink are also maximized as agility is increased. Honeybee Robotics proposes to develop a low cost, high torque and low jitter satellite attitude control actuator derived from its Tiny Operationally Responsive CMG (TORC) design. This derivative product would combine two TORC units into a single scissored-pair configuration with SPA compatible interface. The result, a flight-certified TORC-SP, would be an actuator with the simple control interface of a reaction wheel that offers 1-2 orders of magnitude more torque per unit mass at drastically less power than a reaction wheel.

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GPU-Accelerated Sparse Matrix Solvers for Large-Scale Simulations

EM Photonics

Technical Abstract

At the heart of scientific computing and numerical analysis are linear algebra solvers. In scientific computing, the focus is on the partial differential equations (PDEs) that arise from computational fluid dynamics (CFD), climate modeling, astrophysics, and structural and heat analysis that cannot be solved analytically. Certain problem formulations lead to sparse matrices, in which the majority of matrix elements are zero. Special attention is required when computing on sparse matrices in order to avoid using unrealistic amounts of memory or produce ill-performing software. Such topics have been the subject of considerable research and the limits of CPU-based performance have been reached. Recently, the graphics processing unit (GPU) has emerged as an attractive platform for high performance computing. The modern GPU boasts over 1 TFLOPS performance and as much as 6 GB onboard memory, but harnessing the power can be challenging. A library-based approach is common for HPC, with most applications using several libraries to offload well-known tasks. EM Photonics maintains a library of GPU-accelerated dense linear algebra solvers that has over 5000 users. In this project we will extend this library to include a wide range of sparse solvers, including many that have direct relevance to NASA projects.

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A Sensor Management Tool for Use with NASA World Wind Intelligent Automation, Inc.

Technical Abstract

The number of sensors that are deployed continues to increase for scientific, commercial and intelligence related applications. Quantities of sensor data are increasingly available. NASA and NOAA are generating large quantities of sensor data involving earth, oceans and weather observations. US intelligence and commercial endeavors are also generating vast amounts of sensor data, gathered from sources ranging from satellites to vehicles. Standards have been developed that assist in making the large volume of sensor data usable. The Open Geospatial Consortium (OGC) has developed a number of specifications related to Sensor Web Enablement. OGC working groups are not only science-focused; the newest working group that is forming is an Emergency and Disaster Management Discipline Working Group (DWG). Intelligent Automation Inc (IAI) is proposing to support the data access and utilization needs of the individual researcher / scientist and the emergency incident commander through development of the Sensor Management Tool (SMT). SMT is standards-based, open source and will offer configurable views for different categories of users. In the Phase I effort IAI demonstrated feasibility and prototyped the SMT concept; this involved integration of NASA World Wind to extend SMT functionality. 'Lessons learned' provide input into our detailed plan for full-featured SMT development.

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A 4k-Pixel CTIA Readout for Far IR Photodetector Arrays

TechnoScience Corporation

Technical Abstract

We propose to design a low noise, two-side buttable, 64x64 readout multiplexer with the following key design features: 1- By far the largest readout array developed for far IR detectors to date. Four of these readout can be butted together to form a >16k-pixel mosaic array satisfying the need of the next generation of astronomical instruments. 2- Optimized for use with far infrared detectors requiring low bias levels. The unit-cell design will maintain constant bias across the detector during the integration eliminating non-linearity and detector debiasing. The design will also minimize pixel-to-pixel DC variations which improves the bias uniformity across all pixels of the array. 3- Capable of operation at cryogenic temperatures at least as low as 1.6K. Advanced monolithic cryo-CMOS technology will guarantee deep cryogenic operation with minimal impact on noise performance. 4- Offers the potential of being directly hybridized to IR detector arrays using planar bump-bond technology. This technology has been identified by NASA as well as the science and astronomy community as key for future far IR astronomy. It fits well within the scope of the SBIR Subtopic S1.04 and will be a benefit to many large and small NASA missions including SAFIR/CALISTO and SOFIA.

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TBA- Contract Under Negotiation

Mobile Greenhouse Gas Flux Analyzer for Unmanned Aerial Vehicles

Los Gatos Research

Technical Abstract

Los Gatos Research (LGR) proposes to develop highly-accurate, lightweight, low-power gas analyzers for measurements of carbon dioxide (CO₂) and water vapor (H₂O) aboard NASA's Sensor Integrated Environmental Remote Research Aircraft (SIERRA) unmanned aerial system (UAS). These analyzers, which will exploit both conventional mid and near-infrared tunable diode laser spectrometry and LGR's patented Off-Axis ICOS technology, will be capable of meeting the stringent weight, power, and environmental requirements for UAS deployments. At the conclusion of the Phase II effort, LGR will deliver and deploy two complete systems. The first analyzer will make extremely rapid (> 20 Hz) airborne eddy flux covariance measurements of CO₂ and H₂O. The second instrument will measure CO₂ isotopes aboard SIERRA, allowing a better understanding of the chemistry, transport, and exchange of carbon between the atmosphere, anthropogenic sources, and natural carbon sinks and sources in the terrestrial biosphere. Airborne measurements enable regional-scale investigations of carbon sources and sinks as well as measurements where conventional tower flux deployments are infeasible. These data will complement current satellite observations by providing higher horizontal resolution and vertical profiling, enabling better quantification of carbon sources and sinks. Such deployments are critically important to NASA's Earth Science Division, because they enable more efficient and cost-effective Earth observations.

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TBA- Contract Under Negotiation

Data Reduction Techniques for Real-time Fault Detection and Diagnosis, and Multiple Fault Inference with Imperfect Tests
PowerCube: Integrated Power, Propulsion, and Pointing for CubeSats

Tethers Unlimited

Technical Abstract

The PowerCube is a 1U CubeSat module that provides integrated propulsion, power, and precision pointing to enable the low-cost CubeSat platform to be used to conduct high-performance missions. The PowerCube concept integrates three innovative component technologies to provide these capabilities: First, a Proton Exchange Membrane (PEM) water-electrolysis fuel cell supplies gH₂/gO₂ to a simple pressure-fed thruster to provide 300 Ns of impulse per 100 mL of water. This approach enables the CubeSat to launch with 'inert' propellant to comply with P-POD limitations on stored energy and then process the water on-orbit into high-Isp fuel. Second, a deployable solar array that stows along the long sides of the CubeSat and deploys in a 'windmill' configuration provides up to 96 W peak. Third, a 3DOF 'carpal-wrist' gimbal, in conjunction with magnetic torque coils, enables sun-tracking of the solar panel, vectoring of the thruster, and precision pointing of payloads. The combination of ample power and water electrolysis will provide up to 6 m/s of delta-V per 90 minute orbit for a 3U CubeSat. Compared to other CubeSat propulsion technologies, the PowerCube thruster will enable more rapid orbital maneuvering and significantly lower contamination issues. Our Phase I effort developed a detailed baseline design for the PowerCube, and built and tested a proof-of-concept prototype of the water-electrolysis thruster. The Phase II effort will mature the electrolysis thruster component to the engineering model level, develop and simulate methods for attitude control and precise pointing of both panels and payloads using the gimbal and torque coils, and develop a detailed design for the entire PowerCube module to enable flight validation in follow-on Phase III efforts.

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TBA- Contract Under Negotiation

Notes: • Civil Servants- Would you like to sit in on an SBIR midterm or final briefing? Contact the COTR directly!

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Ground Enterprise Management System

Emergent Space Technologies, Inc.**Technical Abstract**

Emergent Space Technologies Inc. proposes to develop the Ground Enterprise Management System (GEMS) for spacecraft ground systems. GEMS will provide situational awareness for distributed ground systems, and an understanding of how events and automated actions impact the system in real-time. Recent software advancements have improved sustainability, extensibility, fault tolerance, and ease of automation for ground systems. These traits are important for NASA's missions, from Exploration to Earth and Space Science, but can pose challenges, especially when the system has a high degree of interoperability and communications between components that isn't visible to the end-user. Operators can quickly become overwhelmed with the increased complexity of software components constantly exchanging data and the volumes of information being passed around behind-the-scenes. In fact, for largely distributed systems, as much "situational awareness" is needed for the ground system as for the spacecraft itself. GEMS will provide a centralized integration framework that is needed to provide operators with transparency into the ground system, its state, and its component interactions. GEMS will enhance plug-and-play integrations while providing information management and system coordination. The innovation that enables GEMS is the development of "data-driven" algorithms and software adapters that gather data from the various components of the ground system to construct a data model that captures the system state, organizes the data, and displays it to the mission operators.

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Intelliviz - An Intelligent Telemetry Data Visualization Assistant

Stottler Henke Associates, Inc.**Technical Abstract**

Future space programs will require extensive monitoring of complex, highly instrumented systems such as the Orion spacecraft and lunar/Martian habitats. To handle tasks and situations that cannot be fully delegated to automation software, future flight controllers and crew must be able to monitor, review and interpret voluminous and complex telemetry data quickly to maintain necessary levels of situations awareness and make critical decisions rapidly and accurately. We propose to develop Intelliviz, an intelligent telemetry data visualization assistant for NASA. This software system will create data visualizations automatically to reduce the effort and difficulty of specifying and constructing effective telemetry data visualizations. Intelliviz will determine the user's data analysis goals by enabling users to express their data analysis goals directly and by posing system diagnosis or system management questions or problems from which analysis goals can be inferred. Intelliviz will then generate appropriate displays that support the user's data analysis goals by retrieving the relevant telemetry and systems data, selecting appropriate data display methods, and instantiating and configuring those displays. During the prior Phase 1 SBIR project, we reviewed research literature describing prior work in automated visualization design, reviewed related NASA R&D programs, specified scenarios and test cases, identified promising early applications for Intelliviz, refined our requirements and design, implemented a software prototype that demonstrates Intelliviz capabilities, and developed a plan to create an operational prototype during Phase 2. During the phase 2 project proposed in this document, we will develop a technology readiness level 6 operational prototype of Intelliviz to demonstrate its feasibility, utility, and usability by a NASA-relevant user community and task area.

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Intelliface - Intelligent Assistant for Interfacing Diagnosis and Planning Systems

Stottler Henke Associates, Inc.

Technical Abstract

To integrate automated diagnosis and automated planning functions, one must translate diagnosed system faults to corresponding changes in resource availabilities. Implementing reliable translation is challenging, time-consuming, and error prone. We propose to develop Intelliface, an intelligent tool for developing interfaces between diagnosis and planning systems. Intelliface will help ensure that plans are revised appropriately when faults occur in complex space systems. In addition, Intelliface will reduce the effort needed to integrate diagnosis and planning systems. Intelliface will encode and apply a qualitative understanding of generic types of devices and their underlying physics (e.g., electrical storage, distribution, and consumption; fluid flow and storage; signal processing, etc.) in order to identify each activity's direct and indirect resource requirements and their dependencies. Intelliface will use the results of this reasoning to generate resource declarations, updated resource availabilities, and some planning constraints in the planning domain modeling language. In addition, Intelliface will support NASA's top-down systems engineering processes for specifying system functional requirements, performance requirements, and interfaces at each system tier. During Phase 2, we will develop a technology readiness level 6 software prototype that demonstrates the feasibility, utility, and usability of the Intelliface concept within a NASA-relevant environment.

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TBA- Contract Under Negotiation

Notes: • Search government wide for technologies.

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Data Reduction Techniques for Real-time Fault Detection and
Diagnosis, and Multiple Fault Inference with Imperfect Tests

Qualtech Systems

Technical Abstract

Space travel is fraught with ever changing emergencies and accidents that place human life and expensive one-of-a-kind autonomous systems at risk. Hypothetical collisions with space debris, human and computer errors are just a few examples of such risk. In this effort, we propose space based logistics technologies that can ameliorate and minimize the inherent risks due to space travel. We shall adapt agent based logistics technologies developed by 21st Century Technologies for DARPA's Ultra*Log project that can be exploited for use by autonomous systems and by astronauts on shuttle missions. Multiple fidelity processing is one such technology that will be demonstrated to successfully manage a simulated emergency. Multiple fidelity processing manages the level of specificity involved in reasoning about logistics in order to receive a solution in real time. In this effort we shall demonstrate the utility of automated multiple fidelity planning for space based assets in the context of satellite operations to present real time potential solutions to simulated emergency situations. The ability to manage such situations is necessary to promote NASA's vision of filling space with robotic explorers and making operations closer to home more efficient using ever more intelligent automated planners.

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Integrating Prognostics in Automated Contingency Management
Strategies for Advanced Aircraft Controls

Impact Technologies, LLC

Technical Abstract

Automated Contingency Management (ACM) is an emerging and game-changing area of engineering and scientific research that integrates prognostics and health management concept and intelligent control. As leaders in this field, Impact Technologies and Georgia Institute of Technology, propose to build off a strong foundation of ACM research performed with NASA and DARPA in the past few years to both mature the applicability of ACM technology for real aerospace components and push the envelop on the capability and breadth of the technology itself. A prognostics-enhanced, three-tiered ACM architecture for critical aerospace systems has been conceptualized and demonstrated in Phase I. The proposed Phase II effort is focusing on utilizing prognostics at the higher levels of the control hierarchy and is introducing novel concepts to address the fault-tolerant control design at the middle level from the areas of model predictive control, system dynamic inversion, intelligent search techniques, and optimization / system identification algorithms for mission adaptation at the high level. Game theoretic notions are exploited to distribute optimally the available control authority between the components. An electromechanical flight actuator and a UAV platform will be utilized as testbeds for performance evaluation. Significant benefits are anticipated to NASA, DoD, and industry.

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Semantic Summarization for Context Aware Manipulation of Data

TRAC Labs, Inc.**Technical Abstract**

NASA's exploration and scientific missions will produce terabytes of information. As NASA enters a new phase of space exploration, managing large amounts of scientific and operational data will become even more challenging. Robots conducting planetary exploration will produce data for selection and preparation of exploration sites. Robots and space probes will collect scientific data to improve understanding of the solar system. Satellites in low Earth orbit will collect data for monitoring changes in the Earth's atmosphere and surface environment. Key challenges for all these missions are understanding and summarizing what data have been collected and using this knowledge to improve data access. TRAC Labs and CMU propose to develop context aware image manipulation software for managing data collected remotely during NASA missions. This software will filter and search large image archives using the temporal and spatial characteristics of images, and the robotic, instrument, and environmental conditions when images were taken. It also will implement techniques for finding which images show a terrain feature specified by the user. In Phase II we will implement this software and evaluate its effectiveness for NASA missions. At the end of Phase II, context aware image manipulation software at TRL 5-6 will be delivered to NASA.

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Multi-Robot Planetary Exploration Architectures

Aurora Flight Sciences Corporation**Technical Abstract**

Space policy direction is shifting, particularly with respect to human goals. Given the uncertainty of future missions to the moon, Mars, and other bodies, a tool that allows for informed analysis of the option space is particularly relevant. Aurora Flight Sciences and MIT propose to further develop the Multi-Robot Planetary Exploration Architecture (MRPEA) methodology, a suite of software tools and analysis algorithms developed to provide decision aides to architecture planners of planetary surface exploration missions. MRPEA provides 1. A logical and graphical representation of the system space (e.g. interrelated decision variables with constraints), 2. Structural reasoning for rapid exploration of architectural spaces, 3. Simulation, and 4. Results viewing for a set of feasible architectures. Given the robots available or predicted to be available, the expected duration, and the mission goals, our methodology provides analysis results such as knowledge benefit-vs.-mass Pareto front graphs, to allow the designers to provide the best possible architecture for the planned mission or missions. The MRPEA analysis methodology primarily addresses the planning requirements of planetary surface missions, providing useful analyses of the many elements of the architectural decision space; in addition, the principles and techniques developed to analyze and select multi-robot architectures on planetary surfaces can also be applied to future fractional satellite systems, an area of increasing interest.

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Prognostics Enhancement Fault-Tolerant Control with an
Application to a Hovercraft

Impact Technologies, LLC

Technical Abstract

Fault-Tolerant Control (FTC) is an emerging area of engineering and scientific research that integrates prognostics, health management concepts and intelligent control. Impact Technologies and the Georgia Institute of Technology, propose to build off of a strong foundation in fault-tolerant control (FTC) research performed with NASA in past years to mature the applicability of this technology and push the envelope on the capability and breadth of the technology itself. We are introducing for this purpose two novel concepts to expand the scope of fault tolerance and improve the safety and availability of such critical assets. Building upon the successes of Phase I, we will develop and apply to the hovercraft (a targeted testbed) a reconfigurable control strategy that relies on current prognostic information to maintain the platform's stable operation and complete its mission successfully. The second innovation to be introduced refers to a challenging problem encountered in complex systems such as aircraft platforms: A multitude of critical system components can not be monitored directly due to a lack of appropriate sensing modalities. We will introduce a Model Based Reasoning approach and frequency demodulation tools to resolve the ambiguity and "unmask" those fault variables that can not be observed directly.

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Reliable Autonomous Surface Mobility (RASM) in Support of
Human Exploration

ProtoInnovations, LLC

Technical Abstract

ProtoInnovations, LLC and Carnegie Mellon University have formed a partnership to commercially develop rover-autonomy technologies into Reliable Autonomous Surface Mobility (RASM). Our aim is to provide safe and reliable means for lunar rovers to travel at substantial speeds and operate in proximity to astronauts and other vehicles. Our unique partnership brings together state-of-art technologies for autonomous rover navigation with experience in delivering and supporting mobility systems for NASA. The RASM project will create an autonomy framework that is capable of supporting off-road vehicle speeds beyond 3 m/s with planetary-relevant constraints including a lack of infrastructure (such as GPS) and limited communication and computing resources. Our RASM framework is based on environment modeling, obstacle avoidance, path planning, and localization algorithms developed by Carnegie Mellon and proven by hundreds of kilometers of traverse in planetary analog landscapes on Earth. On the RASM project we will mature and package these algorithms in a reliable and portable software architecture that supports a variety of vehicle platforms, sensors, and middleware alternatives. Unique to RASM will be a failure-modes analysis of the autonomy system to model and mitigate hazards posed by operating alongside astronauts and lunar vehicles. Mission constraints and operating scenarios will vary broadly, so RASM will be adaptable. We will develop abstraction layers to enable portability across various vehicle chassis configurations, perception sensors, localization sensors, and communications protocols. In Phase 2 of the project, we will implement the portable architecture developed in Phase 1 and demonstrate its capability on KREX or LATUV vehicles developed by ProtoInnovations.

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Integration of Notification with 3D Visualization of Rover Operations

TRAC Labs, Inc.

Technical Abstract

Future NASA exploration missions will rely on remote operation of robots. As human explorers move further away from Earth, robotic precursors will scout destinations and robotic assistants will perform tasks to reduce astronaut risk and workload. 3D visualization is a key component of how humans will interact with robots for these missions. When the operator engages a robot using visualization, there is a risk that he or she will become too focused on what is happening now in the vicinity of the robot and will not be aware of other important events that are not apparent in the field of view. This risk only increases when operations involve multiple robots. It is essential to ensure that the user does not miss important events that do not manifest in the vicinity of the robot. TRAC Labs, Carnegie Mellon University (CMU), and Stinger Ghaffarian Technologies (SGT) propose to develop software for notifying users of 3D visualization about important notices without distracting users unnecessarily or adding to the visual clutter around the robot avatar. This software will monitor events from the robot or user, identify which events should be brought to the user's attention, and alert users in the 3D pane. The appearance of alerts is altered to shift a user's attention to new notices based on an assessment of the importance and urgency of the notice specific to the user. Thus the same notice may be presented to different users in different ways. Because notices are anchored to a screen overlay, they are visible regardless of what location the user is viewing in the 3D space. In Phase II we will implement this software and evaluate its effectiveness for NASA missions.

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Notes: • What technology searches can the SBIR team do for you?

2011 Phase I Awards (Under Contract Negotiation)

Fast Flow Cavity Enhanced Ozone Monitor
Southwest Sciences, Inc.

Methane Origin Instrument (MOI): Methane Isotope and Hydrocarbon Analyzer for Mars Exploration
Los Gatos Research

Triple Isotope Water Analyzer for Extraplanetary Studies
Los Gatos Research

Glidersonde, a Meteorological Optical Profiling Sensor
Yankee Environment Systems Inc

Lasercom for Intra-Nanosat Communication (LINC)
Honeybee Robotics Ltd.

Echo Time Distance Measurements for Nanosatellite Arrays
American Academy of Aeronautics

Hummingbird - A Very Low Cost, High Delta V Spacecraft for Solar System Exploration
Microcosm, Inc.

Improved CDGPS FDIR Using Comm-based Relative Measurements
Emergent Space Technologies, Inc.

Enhancing the efficiency of Climate and Weather Simulation in High Performance Computing Environments
Tellus Applied Sciences, Inc.

High-Quality Random Number Generation Software for High-Performance Computing
DANIEL H. WAGNER ASSOCIATES, INC.

Cell Phone-based Lateral Flow Assay for Blood Biomarker Detection
Intelligent Optical Systems, Inc.

Smart Phone Fluorescent Chem8
ionu biosystems

Practical Non-contact ECG Electrodes for Prep-free Monitoring
Cognionics Automatic Video-based Motion Analysis
VECNA TECHNOLOGIES INC.

Perception Engine for Activity Recognition and Logging
TRAC Labs, Inc.

Biological Sample Ambient Preservation (BioSAP) Device
ChromoLogic, LLC

Bio-Electrochemical Carbon Dioxide Removal for Air Revitalization in Exploration Life Support Systems
Cambrian Innovation, Inc.

Highly Efficient Fecal Waste Incinerator
UMPQUA Research Company

Advanced Microgravity Compatible, Integrated Laundry System
UMPQUA Research Company

High Performance Forward Osmosis Membrane Element
Porifera Inc.

Adaptive Automation for Anomaly Resolution
TRAC Labs, Inc.

Electronic Health Monitoring for Space Systems
Nokomis, Inc.

Integrated System Health Management for Flexible Exploration
Qualtech Systems, Inc.

Brain Machine Interfaces for Robotic Control in Space Applications
Advanced Medical Electronics Corporation

Visual Intelligent Robot Performance Monitor
Stottler Henke Associates, Inc.

Temperature, Heat Flux and Recession Sensing for Ablative Thermal Protection Systems

Industrial Measurement Systems Inc.
Aerospace Grade Carbon Felt Preform
Fiber Materials, Inc.

Advanced Metal Rubber Sensors for Hypersonic Decelerator Entry Systems
Nanosonic, Inc.

Biomining of regolith simulants for biological in situ resource utilization
Universal Bio Mining, LLC

An Electrochemical, Point-of-Care Detector for Reagent-free, In-situ Diagnostics of Pathogens
CFD Research Corporation

Evolutionary Autonomous Health Monitoring System (EAHMS)
American GNC Corporation

Anytime Summarization for Remote Robot Operations
TRAC Labs, Inc.

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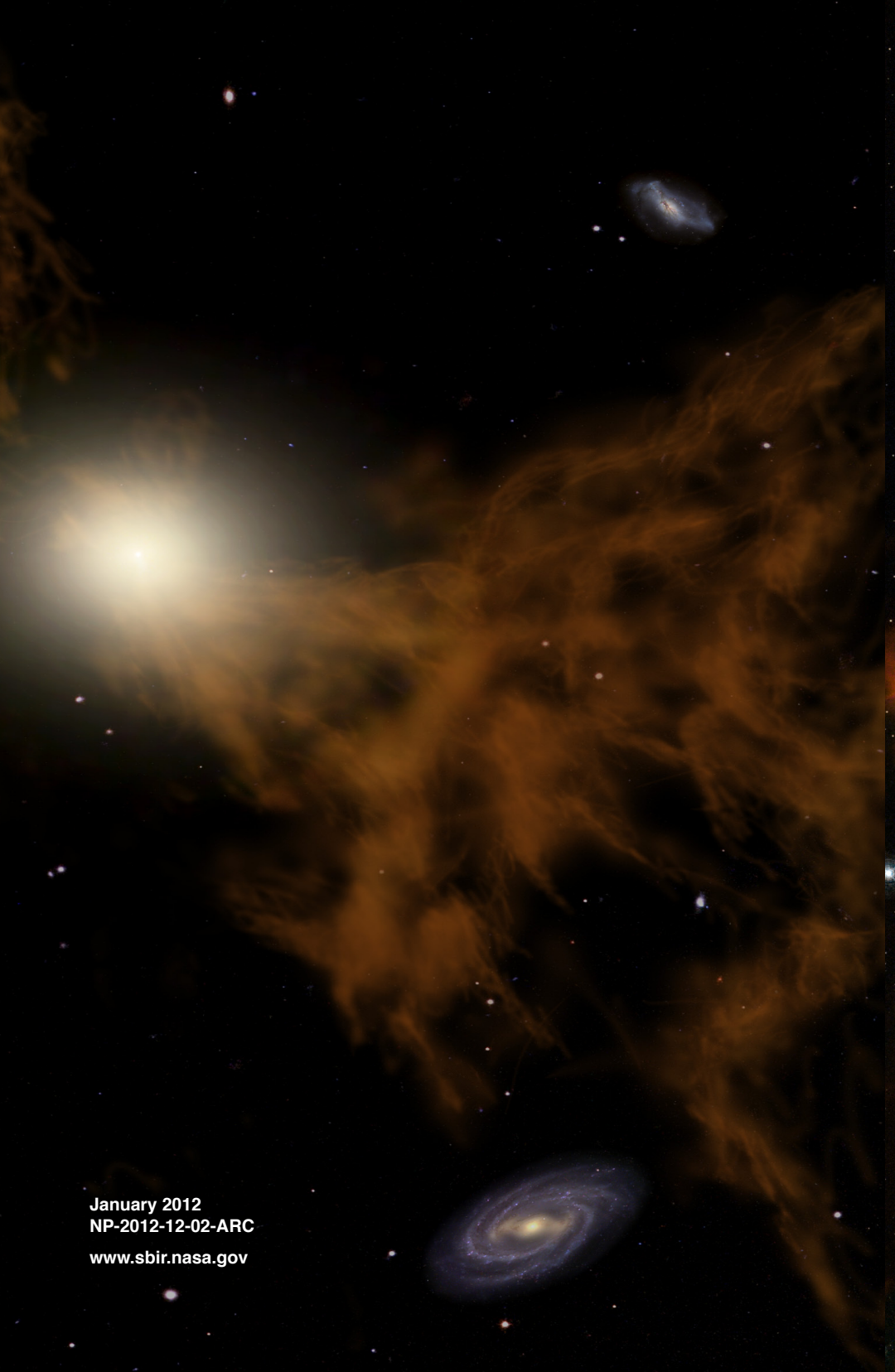
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